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EXPERIMENTAL TAGGING OF THE NORTHERN ANCHOVY, *ENGRAULIS MORDAX*[1]

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A practical and feasible method of tagging northern anchovies was found in a series of experiments conducted in live bait tanks in San Diego Bay. A small steel tag was inserted into the visceral cavity. An antibiotic paste of 10% tetracycline was required on the tag to prevent infection. Greater mortality occurred among fish anesthetized during tagging than among those tagged without anesthetic. Better survival occurred in freshly caught anchovies than in fish which had been held in the tanks for a few days.

INTRODUCTION

A tagging program may be needed in the near future to investigate the population structure, movement, and abundance of the northern anchovy. Studies of migration and population structure of pelagic fishes have been accomplished by tagging individual fish and by recovering them at extended time intervals (Hart and Tester, 1937; Clark and Janssen, 1945). The insertion of tags into pelagic fish is usually traumatic, and may result in a high initial mortality. Anchovies are notoriously susceptible to injury when handled, so a feasibility study was conducted to determine whether they could be tagged successfully. The experiments were designed to test the effects of several factors on fish mortality and tag loss: (i) anesthetic, (ii) tag size, (iii) handling, (iv) antibiotic, and (v) tagging conditioned and unconditioned fish.

Since the major souree of tag returns in a tagging program would be from commercial canneries and reduction plants, metal tags would be required because they can be recovered by magnets or metal deteetors in conveyors and reduction lines. A small nickel-plated steel internal tag (13 x 3 x 0.5 mm) with rounded ends was chosen. This type of tag has been used successfully on Pacific sardines, *Sardinops caeruleus* (Hart, 1937; Janssen and Aplin, 1945), Pacific herring, *Clupea pallasii* (Hart and Tester, 1937), and anchovetas, *Cetengraulis mysticetus* (Bayliff and Klima, 1962).

A preliminary experiment was performed to find a suitable place on the fish for tag insertion. Several anchovies were anesthetized in a solution of 7 ppm. quinaldine (2-methylquinoline, Eastman P216). A tag was inserted into the body cavity of each fish through a small incision through the lateral wall. These incisions were made by scalpel at various locations along the side and belly of the fish. All tags were inserted by pushing them anteriorly through the incision with small

[1] Submitted for publication May 1966.

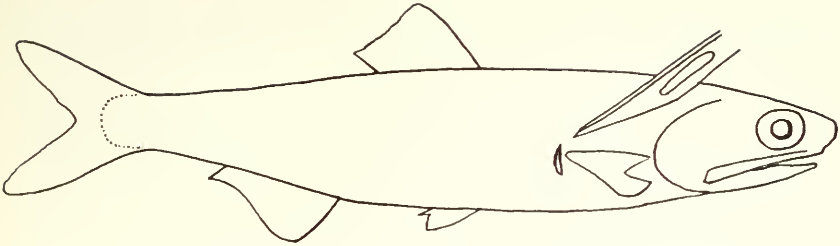

FIGURE 1. Location of incision for tag insertion.

forceps. The tagged fish were held in a small enclosure for 2 hours, killed, and dissected to determine the ultimate location of the tag and the amount of injury to internal organs. All the fish lived through this 2-hour test, although some sustained organ damage that probably would have been fatal. The most promising location for tag insertion appeared to be just dorsal to the tip of the pectoral fin (Figure 1). Fish tagged in this way showed no visible organ damage. The tags were inserted anteriorly through the incision, but the body movements of the fish moved the tags posteriorly past the point of insertion, where they lodged in a ventro-lateral position just anterior to the vent.

All anchovies used in our experiments were caught by commercial bait fishermen and placed in receivers at a live-bait barge anchored in San Diego Bay. The experiments were conducted in four, 5 x 10-foot enclosures, 5 feet deep. The sides of the enclosures were ⅝-inch-mesh nylon netting, and the bottoms were plastic window screening with mesh fine enough to retain any tags the anchovies might lose. Shed tags were collected daily by sweeping the bottom of the enclosure with a magnet.

EXPERIMENTS

Experiment I: Anesthesia but no Control of Infection

In the first experiment (I), 200 anchovies were anesthetized, tagged, and released into one of the enclosures; 200 others were placed in an adjoining enclosure as controls. The control fish were handled in exactly the same manner as the tagged fish, including anesthetization and making an incision through the body wall, but no tags were inserted. This procedure was intended to distinguish the mortality caused by handling from that directly attributable to the tags. One hour after the tagging was completed, all dead fish were removed. This immediate mortality was deducted from the original number tagged and the remaining fish were considered successfully tagged. Because the immediate mortality varied considerably among experiments, all the calculations reported in this paper are based on percentages of the successfully tagged fish or living controls.

During the first five days, 18.3% of the controls and 31.6% of the tagged fish died. The mortality of tagged fish increased on the sixth day and continued at a high rate, but mortality among the controls decreased (Table 1, Figure 2). The high mortality of tagged fish after the sixth day appeared to be caused by a heavy bacterial infection; the internal organs were inflamed and edemic. No effort had been made to

maintain sterile conditions during tagging. The experiment was terminated after 11 days, when 80.2% of the tagged fish and 19.3% of the control fish had died.

TABLE 1

Experiment Number I—Mortality in 200 Tagged Anchovies and 200 Control Fish

Days after tagging	Mortality of tagged fish		Mortality of control fish	
	Number	Percentage*	Number	Percentage*
0†	13		8	
1	15	8.0	5	2.6
2	15	8.0	13	6.8
3	14	7.5	4	2.1
4	5	2.7	8	4.2
5	10	5.4	5	2.6
6	20	10.7	1	0.5
7	18	9.6	0	0
8	24	12.8	1	0.5
9	17	9.1	0	0
10	9	4.8	0	0
11	3	1.6	0	0
Totals	**150**	**80.2**	**37**	**19.3**

* The values are percentages of tagged or control fish alive after 1 hour.
† Immediate mortality, fish dead within 1 hour after completion of tagging (not included in totals).

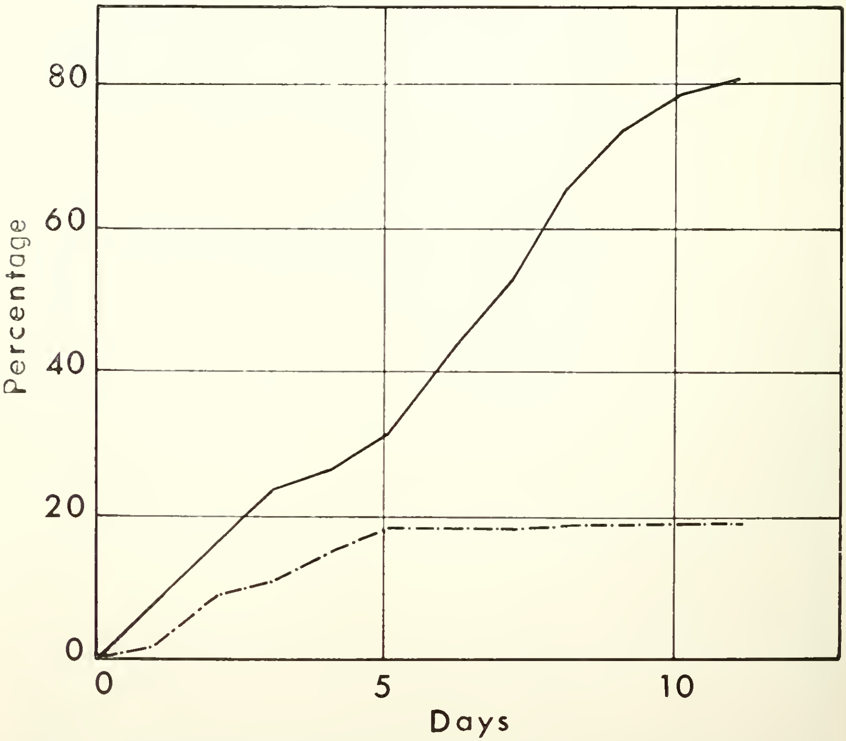

FIGURE 2. Experiment I. Cumulative percentage mortality among anchovies tagged with regular-size tags (solid line) and control fish (broken line). The data are from Table 1.

Experiment II: Control of Infection Attempted; Tag Size Tested

The second experiment (IIa, b, c), designed to test methods of preventing the bacterial infection observed in experiment I, and to determine if tag size had any effect on survival, consisted of three separate tests and a control. All the tags and instruments were soaked in 90% alcohol to reduce bacterial contamination. The tags were air dried on a sterile surface before insertion. Scalpel blades and forceps were wiped with alcohol after each fish was handled.

In experiment IIa, 200 anchovies were tagged with sterilized regular-size tags (13 x 3 x 0.5 mm) without antibiotic. In experiment IIb, 200 fish were tagged with the same size tags coated with an antibiotic paste of 10% tetracycline HCl in sterile petrolatum. Tetracycline was chosen because it is a broad-spectrum antibiotic with an apparently low toxicity to fish. It has a secondary advantage of making a mark on otoliths and bones after it is administered (Kobayashi, 1964); this could provide additional information on age and growth. The paste form was used because it could be applied with the tag in a single operation, thus eliminating the additional time and handling of fish required for injection of the antibiotic.

In experiment IIc, 200 anchovies were marked with tags approximately half the size of the regular tags (6 x 3 x 0.5 mm), without antibiotic. Again 200 anchovies were used for controls and were handled exactly like the controls in experiment I.

Immediate mortality (fish dead within one hour after tagging) was 47 in the control, 54 in IIa, and 66 in IIc. These losses, which were considerably higher than those in experiment I, appeared to be caused by over-anesthesia. In test IIb, the length of time the fish were anesthetized was shortened by putting fewer fish at a time in the anesthetic; the immediate mortality was only 16 fish in this group.

Maintenance of sterile conditions during tagging appeared to be advantageous. The increase in infection-induced mortality after the sixth day was again noted in the fish tagged with the regular-size tag without antibiotic (experiment IIa, Table 2, Figure 3), but the rate of loss was only about half that of experiment I. Total mortality after 26 days amounted to 61.6% of the successfully tagged fish. The antibiotic on the regular-size tag in experiment IIb reduced the mortality even further, to 21.2%, but the lowest mortality was observed in IIc—fish tagged with the small tag without antibiotic. In IIc the total loss was only 3.7% after 26 days. The smaller tag probably lessened mortality by reducing mechanical injury and infectious material.

Each day all dead fish were dissected and examined, tag locations were noted, and visible internal damage was recorded. Three fish from experiment IIa and two from IIb died after thay had shed their tags. These fish were not included in the daily mortality because they had already been accounted for in the tags-shed and mortality-plus-tags-shed columns (Table 2).

Tag shedding, which did not occur during the short duration of experiment I, was important in experiment II. More regular-size tags with antibiotic were shed (22.3%) than regular tags without antibiotic (11.6%). Two factors were involved: the antibiotic tended to inhibit healing of the incision, and the high mortality of fish in IIa probably accounted for some fish that would have shed tags later. The small

TABLE 2

Experiment Number II—Mortality and Tag Loss in 600 Tagged Anchovies (200 in Each Experimental Lot) and 200 Control Fish

Days after tagging	Experiment IIa Regular tags (13 x 3 x 0.5 mm) without antibiotic						Experiment IIb Regular tags (13 x 3 x 0.5 mm) with antibiotic						Experiment IIc Small tags (6 x 3 x 0.5 mm) without antibiotic						Control	
	Mortality		Tags shed		Mortality plus tags shed		Mortality		Tags shed		Mortality plus tags shed		Mortality		Tags shed		Mortality plus tags shed		Mortality	
	No.	%*	No.	%*	No.	%*	No.	%*	No.	%*	No.	%*	No.	%*	No.	%*	No.	%*	No.	%*
†0	54		0		54		16		0		16		66		0		66		17	
1	4	2.7	3	2.0	7	4.8	3	1.6	8	4.5	11	6.0	3	2.2	6	4.5	9	6.7	2	1.3
2	11	7.5	0	0	11	7.5	2	1.1	0	0	2	1.1	0	0	0	0	0	0	3	2.0
3	0	0	0	0	0	0	1	0.5	7	3.8	8	4.3	0	0	1	0.8	1	0.8	0	0
4	1	0.7	0	0	1	0.7	3	1.6	1	0.5	4	2.2	0	0	2	1.5	2	1.5	1	0.6
5	4	2.7	1	0.7	5	3.4	3	1.6	2	1.1	5	2.7	1	0.8	3	2.2	4	3.0	0	0
6	4	2.7	0	0	4	2.7	0	0	0	0	0	0	0	0	1	0.8	1	0.8	0	0
7	18	12.3	0	0	18	12.3	3	1.6	2	1.1	5	2.7	1	0.8	2	1.5	3	2.2	0	0
8	9	6.2	0	0	9	6.2	2	1.1	0	0	2	1.1	0	0	1	0.8	1	0.8	0	0
9	7	4.8	1	0.7	8	5.5	6	3.3	1	0.5	7	3.8	0	0	2	1.5	2	1.5	0	0
10	5	3.4	0	0	5	3.4	5	2.7	0	0	5	2.7	0	0	1	0.8	1	0.8	1	0.6
11	3	2.0	1	0.7	4	2.7	1	0.5	3	1.6	4	2.2	0	0	2	1.5	2	1.5	0	0
12	3	2.0	2	1.4	5	3.4	1	0.5	2	1.1	3	1.6	0	0	4	3.0	4	3.0	0	0
13	2	1.4	2	1.4	4	2.7	0	0	3	1.6	3	1.6	0	0	1	0.8	1	0.8	0	0
14	0	0	0	0	0	0	0	0	2	1.1	2	1.1	0	0	5	3.7	5	3.7	0	0
15	1	0.7	1	0.7	2	1.4	1	0.5	1	0.5	2	1.1	0	0	0	0	0	0	0	0
16	1	0.7	0	0	1	0.7	1	0.5	2	1.1	3	1.6	0	0	4	3.0	4	3.0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	1	0.7	1	0.7	2	1.4	0	0	2	1.1	2	1.1	0	0	2	1.5	2	1.5	1	0.6
19	0	0	1	0.7	1	0.7	0	0	2	1.1	2	1.1	0	0	0	0	0	0	0	0
20	0	0	2	1.4	2	1.4	2	1.1	0	0	2	1.1	0	0	3	2.2	3	2.2	0	0
21	1	0.7	0	0	1	0.7	0	0	1	0.5	1	0.5	0	0	3	2.2	3	2.2	0	0
22	1	0.7	2	1.4	3	2.0	0	0	0	0	0	0	0	0	2	1.5	2	1.5	0	0
23	3	2.0	0	0	3	2.0	1	0.5	1	0.5	2	1.1	0	0	0	0	0	0	2	1.3
24	4	2.7	0	0	4	2.7	1	0.5	1	0.5	2	1.1	0	0	1	0.8	1	0.8	0	0
25	2	1.4	0	0	2	1.4	1	0.5	0	0	1	0.5	0	0	1	0.8	1	0.8	0	0
26	2	1.4	0	0	2	1.4	0	0	0	0	0	0	0	0	1	0.8	1	0.8	0	0
Totals	87	59.6	17‡	11.6	104	71.2	37	20.1	41‡	22.3	73	42.4	5	3.7	43	35.8	53	39.6	10	6.5

* The values are percentages of tagged or control fish alive after one hour.

† Immediate mortality, fish dead within one hour after completion of tagging (not included in totals).

‡ Three fish from experiment IIa that had shed tags and two from IIb subsequently died. They were not included in the mortality column because they had already been accounted for in the mortality-plus-tags-shed column.

tags were shed more rapidly (35.8%) than the regular-size tags with or without antibiotic, presumably because the shorter length of the small tag allowed it to orient more readily to the position of the wound.

Experiment III: Method of Inserting Tag; Tagging Without Anesthetic

Experiment III was designed to see if the amount of shedding (22.3% in IIb and 35.8% in IIc) could be cut down by inserting tags through the incision posteriorly rather than anteriorly, and to test the effect of tagging without anesthetic.

Tags inserted anteriorly were usually moved caudad by the body movements of the fish. It was postulated that if the tags were inserted posteriad originally they would have less chance to move past the open wound and be shed. Experiment III consisted of three separate tests in which all the tags were inserted posteriorly. In experiment IIIa, 200 anchovies were tagged with the regular-size tags without antibiotic; in IIIb, 200 fish were tagged with the regular-size tags with tetracycline antibiotic; in IIIc, 200 fish were tagged with the small tag without antibiotic; and 200 anchovies served as controls. No anesthetic was used in any of the tests or the control. Immediate mortality accounted for only 1 of the 200 control fish and none of the 600 tagged anchovies.

In experiment IIIa, the mortality was very high (91.0%), and appeared to be caused by extremely heavy infection, even though the sterile conditions of the previous experiments were maintained (Table 3, Figure 4). We believe that the infection was fostered by the warmer water, which averaged 67.2° F, compared with 63.9° F during experiment II. The effectiveness of the antibiotic can be seen readily in experiment IIIb, which differed from IIIa only in the use of the tetracycline paste. The mortality in IIIb (28.0%) was much less than in IIIa (91.0%). In experiment IIIc (fish tagged with the small tags without antibiotic) mortality also increased to 30.0%, compared with 3.7% in the previous experiment.

During the last six days of experiment III, water in San Diego Bay was extremely dirty and a heavy oil slick appeared around the bait receivers. These water conditions may have contributed to the increased mortality during that period.

Insertion of tags in a posterior direction reduced the amount of shedding among fish that were tagged with the regular-size tags from 11.6% in IIa and 22.3% in IIb, to 2.5% in IIIa and 12.5% in IIIb, but increased the shedding of the small tags to 58.5% in IIIc from 35.8% in IIc. When the tags were inserted anteriorly, one or two scales were removed and the incision was slanted in the direction of the scale pocket. To insert the tags in a posterior direction, more scales usually had to be removed and the incision was made at about a right angle to the body. Insertion of the tag was more difficult, and often caused a slightly larger wound, which in turn probably facilitated loss of the small tags but not the larger ones. Three of the fish tagged with the small tags (IIIc) died after they had shed their tags; they were not included in the daily mortality because they had already been accounted for in the tags-shed and mortality-plus-tags-shed columns (Table 3).

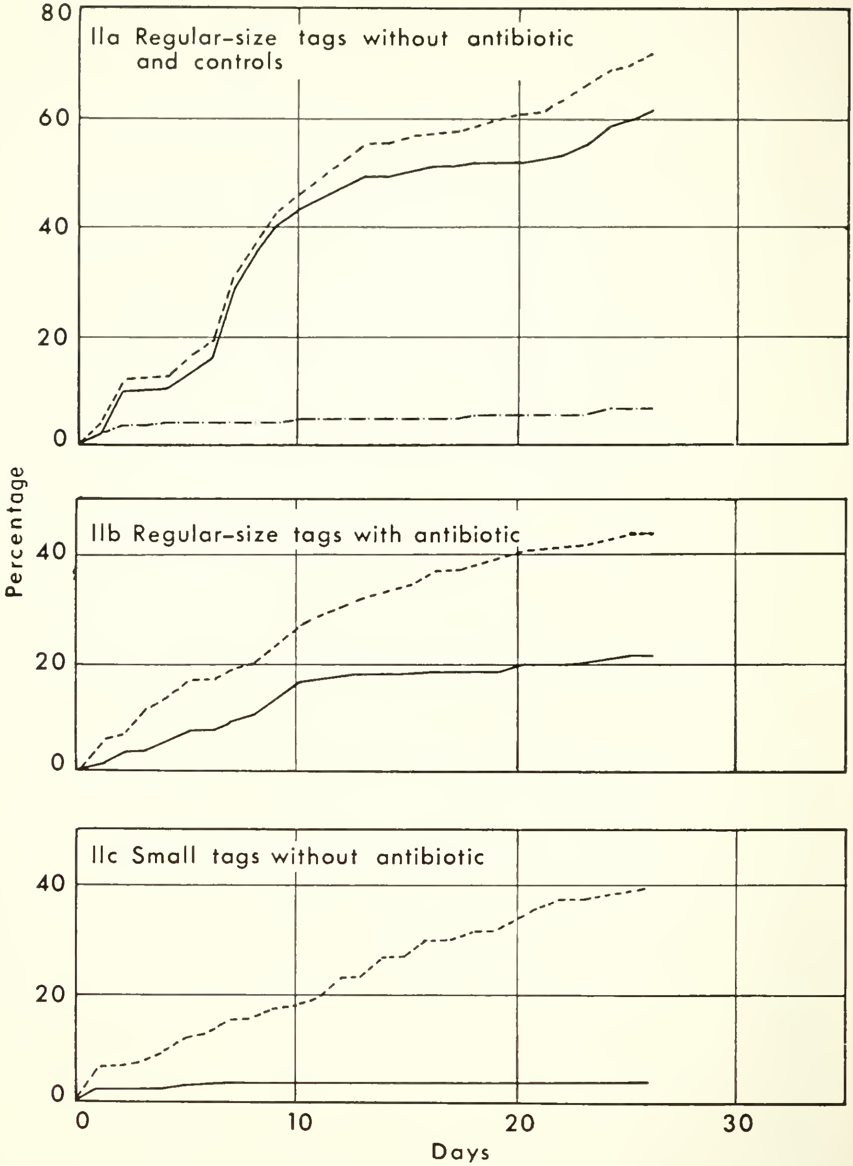

FIGURE 3. Experiment II. Cumulative percentage mortality and tag loss in tagged anchovies and control fish under different experimental conditions. Solid line shows cumulative mortality; dashed line, cumulative mortality plus shed tags; dot and dash line in Figure IIa shows cumulative mortality of controls. Graphs based on data from Table 2.

TABLE 3

Experiment Number III—Mortality and Tag Loss in 600 Anchovies (200 in Each Experimental Lot) and 200 Control Fish

Days after tagging	Experiment IIIa Regular tags (13 x 3 x 0.5 mm) without antibiotic						Experiment IIIb Regular tags (13 x 3 x 0.5 mm) with antibiotic						Experiment IIIc Small tags (6 x 3 x 0.5 mm) without antibiotic						Control	
	Mortality		Tags shed		Mortality plus tags shed		Mortality		Tags shed		Mortality plus tags shed		Mortality		Tags shed		Mortality plus tags shed		Mortality	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%*
†0	0		0		0		0		0		0		0		0		0		1	
1	1	0.5	0	0	1	0.5	0	0	0	0	0	0	2	1.0	0	0	2	1.0	1	0.5
2	4	2.0	1	0.5	5	2.5	3	1.5	1	0.5	4	2.0	11	5.5	0	0	11	5.5	0	0
3	5	2.5	0	0	5	2.5	1	0.5	0	0	1	0.5	8	4.0	0	0	8	4.0	1	0.5
4	14	7.0	0	0	14	7.0	0	0	0	0	0	0	3	1.5	0	0	3	1.5	0	0
5	23	11.5	0	0	23	11.5	1	0.5	0	0	1	0.5	3	1.5	0	0	3	1.5	0	0
6	34	17.0	0	0	34	17.0	1	0.5	0	0	1	0.5	0	0	1	0.5	1	0.5	0	0
7	34	17.0	0	0	34	17.0	5	2.5	0	0	5	2.5	0	0	0	0	0	0	0	
8	24	12.0	0	0	24	12.0	4	2.0	0	0	4	2.0	0	0	7	3.5	7	3.5	0	0
9	13	6.5	0	0	13	6.5	5	2.5	0	0	5	2.5	0	0	10	5.0	10	5.0	0	0
10	11	5.5	0	0	11	5.5	2	1.0	1	0.5	3	1.5	0	0	11	5.5	11	5.5	1	0.5
11	4	2.0	0	0	4	2.0	2	1.0	0	0	2	1.0	0	0	12	6.0	12	6.0	1	0.5
12	3	1.5	0	0	3	1.5	0	0	1	0.5	1	0.5	0	0	9	4.5	9	4.5	1	0.5
13	2	1.0	0	0	2	1.0	2	1.0	1	0.5	3	1.5	2	1.0	13	6.5	15	7.5	0	0
14	1	0.5	1	0.5	2	1.0	0	0	2	1.0	2	1.0	2	1.0	3	1.5	5	2.5	0	0
15	1	0.5	0	0	1	0.5	3	1.5	1	0.5	4	2.0	0	0	9	4.5	9	4.5	2	1.0
16	0	0	0	0	0	0	0	0	5	2.5	5	2.5	1	0.5	7	3.5	8	4.0	0	0
17	1	0.5	0	0	1	0.5	0	0	2	1.0	2	1.0	0	0	4	2.0	4	2.0	1	0.5
18	1	0.5	0	0	1	0.5	1	0.5	2	1.0	3	1.5	1	0.5	1	0.5	2	1.0	2	1.0
19	0	0	0	0	0	0	3	1.5	1	0.5	4	2.0	0	0	8	4.0	8	4.0	0	0
20	0	0	2	1.0	2	1.0	4	2.0	0	0	4	2.0	0	0	4	2.0	4	2.0	0	0
21	1	0.5	0	0	1	0.5	2	1.0	1	0.5	3	1.5	0	0	3	1.5	3	1.5	2	1.0
22	1	0.5	0	0	1	0.5	3	1.5	1	0.5	4	2.0	0	0	2	1.0	2	1.0	2	1.0
23	1	0.5	0	0	1	0.5	0	0	1	0.5	1	0.5	1	0.5	2	1.0	3	1.5	2	1.0
24	0	0	0	0	0	0	2	1.0	2	1.0	4	2.0	1	0.5	2	1.0	3	1.5	0	0
25	0	0	0	0	0	0	2	1.0	0	0	2	1.0	0	0	0	0	0	0	3	1.5
26	0	0	0	0	0	0	0	0	0	0	0	0	1	0.5	1	0.5	2	1.0	2	1.0
27	0	0	0	0	0	0	1	0.5	1	0.5	2	1.0	2	1.0	3	1.5	5	2.5	1	0.5
28	1	0.5	0	0	1	0.5	4	2.0	0	0	4	2.0	0	0	3	1.5	3	1.5	0	0
29	1	0.5	0	0	1	0.5	1	0.5	1	0.5	2	1.0	0	0	1	0.5	1	0.5	0	0
30	1	0.5	0	0	1	0.5	1	0.5	0	0	1	0.5	0	0	1	0.5	1	0.5	2	1.0
31	0	0	0	0	0	0	0	0	0	0	0	0	6	3.0	0	0	6	3.0	2	1.0
32	0	0	0	0	0	0	0	0	0	0	0	0	6	3.0	0	0	6	3.0	3	1.5
33	0	0	0	0	0	0	0	0	1	0.5	1	0.5	6	3.0	0	0	6	3.0	3	1.5
34	0	0	1	0.5	1	0.5	3	1.5	0	0	3	1.5	4	2.0	0	0	4	2.0	2	1.0
Totals	132	91.0	5	2.5	137	93.5	53	23.0	25	12.5	81	40.5	60	30.0	117‡	53.5	177	83.5	34	17.0

* The values are percentages of control fish alive after one hour.
† Immediate mortality, fish dead within one hour after completion of tagging (not included in totals).
‡ Three of these fish that had shed tags subsequently died. They were not included in the mortality column because they had already been accounted for in the mortality-plus-tags-shed column.

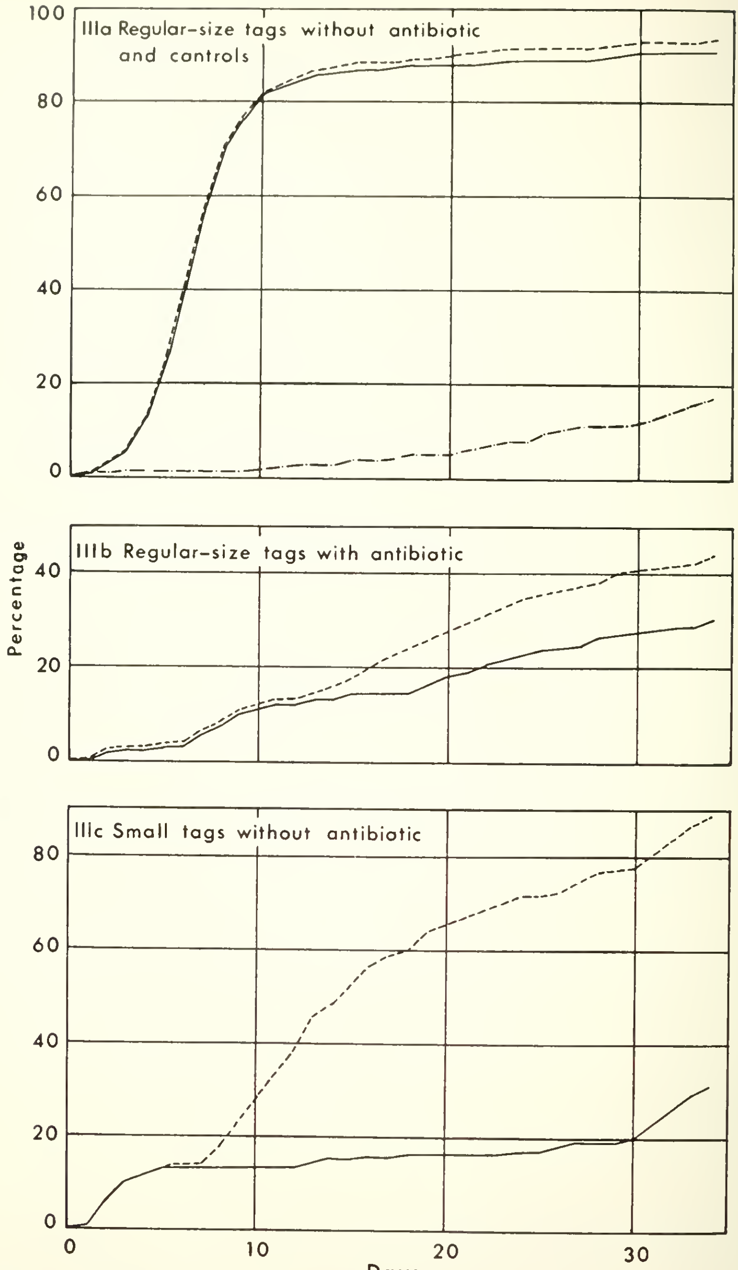

FIGURE 4. Experiment III. Cumulative percentage mortality and tag loss in tagged anchovies and control fish under different experimental conditions. Solid line shows cumulative mortality; dashed line, cumulative mortality plus shed tags; dot and dash line in Figure IIIa shows cumulative mortality of controls. Graphs based on data from Table 3.

Experiment IV: Non-conditioned Fish

All of the anchovies used in the first three experiments had been "conditioned" by holding them in a live bait receiver for a few days before tagging. To determine if conditioning was necessary or even useful, experiment IVa was set up with 200 freshly caught anchovies. They were tagged with the regular-size tags with tetracycline antibiotic paste, without the use of an anesthetic. The control consisted of 200 freshly caught fish. After 35 days only 10.5% of the tagged fish and 8.5% of the controls had died (Table 4, Figure 5). This is a much lower mortality than that observed in the similarly tagged conditioned fish of experiments IIb (22.3%) and IIIb (12.5%). The amount of tag shedding (9.5%) was also low. Only 20% of the fish were lost through both tag shedding and mortality at the end of 35 days.

TABLE 4

Experiment Number IV—Mortality and Tag Loss in 200 Tagged Unconditioned Anchovies and 200 Control Fish

Days after tagging	Experiment IVa Regular tags (13 × 3 × 0.5 mm) with antibiotic Mortality Number	Mortality Percent	Tags shed Number	Tags shed Percent	Mortality plus tags shed Number	Mortality plus tags shed Percent	Control Mortality Number	Control Mortality Percent
0	0		0		0		0	
1	0	0	1	0.5	1	0.5	4	2.0
2	1	0.5	0	0	1	0.5	2	1.0
3	5	2.5	0	0	5	2.5	4	2.0
4	1	0.5	0	0	1	0.5	3	1.5
5	3	1.5	0	0	3	1.5	0	0
6	1	0.5	0	0	1	0.5	1	0.5
7	1	0.5	0	0	1	0.5	0	0
8	1	0.5	0	0	1	0.5	0	0
9	0	0	1	0.5	1	0.5	0	0
10	1	0.5	0	0	1	0.5	0	0
11	0	0	0	0	0	0	0	0
12	0	0	1	0.5	1	0.5	0	0
13	0	0	1	0.5	1	0.5	0	0
14	0	0	0	0	0	0	0	0
15	1	0.5	0	0	1	0.5	0	0
16	1	0.5	1	0.5	2	1.0	0	0
17	0	0	2	1.0	2	1.0	0	0
18	1	0.5	1	0.5	2	1.0	0	0
19	0	0	1	0.5	1	0.5	0	0
20	1	0.5	1	0.5	2	1.0	0	0
21	0	0	0	0	0	0	0	0
22	0	0	1	0.5	1	0.5	0	0
23	0	0	0	0	0	0	0	0
24	1	0.5	0	0	1	0.5	1	0.5
25	0	0	1	0.5	1	0.5	0	0
26	0	0	1	0.5	1	0.5	1	0.5
27	1	0.5	0	0	1	0.5	0	0
28	0	0	1	0.5	1	0.5	0	0
29	0	0	1	0.5	1	0.5	0	0
30	0	0	1	0.5	1	0.5	0	0
31	0	0	1	0.5	1	0.5	1	0.5
32	0	0	1	0.5	1	0.5	0	0
33	0	0	0	0	0	0	0	0
34	1	0.5	2	1.0	3	1.5	0	0
35	0	0	0	0	0	0	0	0
Totals	**21**	**10.5**	**20**	**10.0**	**41**	**20.5**	**17**	**8.5**

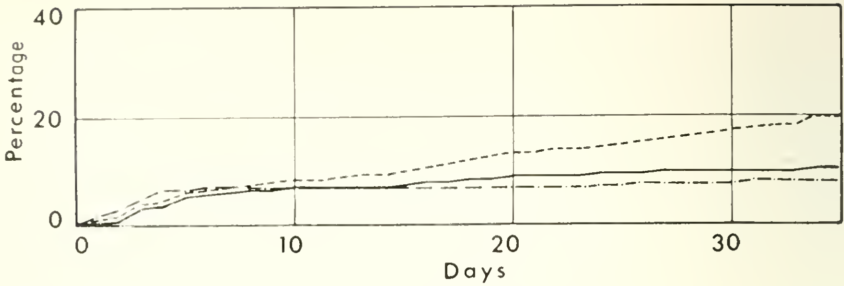

FIGURE 5. Experiment IV. Cumulative percentage mortality and tag loss in tagged unconditioned anchovies and control fish. Solid line shows cumulative mortality; dashed line, cumulative mortality plus shed tags; dot and dash line shows cumulative mortality of controls. The data are from Table 4.

Again it was demonstrated that the anesthetic was not needed. Neither the tagged group nor the control suffered any immediate mortality. Immediate mortality accounted for 204 of the 1,200 fish which had been anesthetized, but only 1 of the 1,200 handled without anesthetic (Table 5).

It would have been desirable to continue some of the experiments over a longer period, but the lack of holding space in the receivers necessitated restriction of each group of tests to about one month. If an actual anchovy tagging program is started, it would be desirable to make some longer-term experiments on a larger scale to determine more precisely the total loss of tagged fish (actual mortality plus shed tags) before tagging data are used in calculating population numbers. It is possible, however, to speculate on the tag-shedding aspect of long-term experiments. Most of the shedding had probably occurred by the end of 30 days. All the fish alive at the end of the experiments were dissected, and the tags were removed. In most, the wounds were com-

TABLE 5

Immediate Mortality (Fish Dead Within One Hour After Tagging) in Tagged and Control Anchovies, Handled With and Without Anesthetic

Experiment number	Number of anchovies used	Immediate mortality	Successfully tagged or control fish
Anesthetic used			
I	200	13	187
I Control	200	8	192
IIa	200	54	146
IIb	200	16	184
IIc	200	66	134
II Control	200	47	153
Anesthetic not used			
IIIa	200	0	200
IIIb	200	0	200
IIIc	200	0	200
III Control	200	1	199
IVa	200	0	200
IV Control	200	0	200

pletely healed and covered with new scales; in a few, the tip of the tag protruded outside the fish. Generally, the fish showed little ill effect from the tags which were encysted along the body wall, the gonads, the intestines, or the mesentery. Occasionally a tag was imbedded in the intestines, gonad, or liver, and the general condition of the fish appeared poor. Janssen and Aplin (1945), who used a similar tag on sardines, observed that the amount of shedding decreased rapidly after 20 to 25 days. Bayliff and Klima (1962) stated that most of the shedding of internal tags by anchovetas took place within the first month after tagging.

CONCLUSION

Tagging of northern anchovies with metal internal tags is feasible. The best results were obtained by using 13 x 3 x 0.5-mm nickel-plated steel tags coated with tetracycline paste and inserted posteriorly through an incision cut just dorsal to the tip of the pectoral fin. Freshly caught anchovies may be tagged without the use of an anesthetic.

SUMMARY

1) A total of 1,600 northern anchovies was tagged with metal internal tags; an additional 800 served as controls.
2) Maintenance of sterile conditions during tagging reduced the mortality over that from tagging under non-sterile conditions.
3) The mortality was less in anchovies marked with tags approximately half the size of the regular tags, but increased shedding of the smaller tags offset this advantage.
4) Mortality was reduced greatly by use of an antibiotic paste on the regular-size tags, but shedding was increased slightly. Insertion of the tags in a posterior instead of an anterior direction somewhat reduced shedding.
5) Freshly caught anchovies survived tagging better than "conditioned" fish.
6) Immediate mortality accounted for 204 of the 1,200 fish which had been anesthetized but only 1 of the 1,200 handled without an anesthetic.

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THE LAKE TAHOE SPORT FISHERY[1]

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Lake Tahoe is a deep, cold, extremely oligotrophic lake located in the Sierra Nevada of California and Nevada. Tahoe anglers can be divided into four distinct categories: topline, deepline, shore, and pier anglers. These groups had dissimilar success rates and catch compositions. In terms of the lake's natural fishery, deepliners had the highest and most consistent success and caught lake trout almost exclusively. Topline success was next, with the catch composed primarily of wild rainbow trout, followed by lake trout and then brown trout. Pier anglers were the next most successful group and took mostly wild rainbow trout, followed by mountain whitefish. Least successful were the shore anglers, who caught mostly wild rainbow trout. Planted trout increased success rates substantially, benefiting largely the shore and pier anglers and to some extent the topliners. The lake trout was the dominant game fish in the catch, comprising about 70% by number of all wild trout. Lake trout averaged 18.5 inches FL. Largest specimens were taken in the winter, intermediate sizes in the summer, and smallest ones in October. Estimated lake trout yield was about 0.24 pounds per acre per year. A stable lake trout fishery is indicated and no changes in angling regulations are recommended. Some evidence indicates that Lake Tahoe under present conditions may be close to its potential game fish yield. On the other hand, it is possible that the yield may be increased; e.g., by more efficient utilization of potential productivity of the limnetic zone by an open-water game fish.

INTRODUCTION

Since the native cutthroat[2] fishery collapsed in the early 1930's, fishing in Lake Tahoe has had a poor reputation. Despite the establishment of several exotic game fishes and other management efforts by Nevada and California, anglers remained generally dissatisfied. Consequently, the two states' fish and game agencies, sportsmen, and local legislators agreed that a joint research effort was needed to find and test methods of improving fishing.

The cooperative Lake Tahoe Fisheries Study was initiated by Nevada and California on July 1, 1960. During its early stages, emphasis was placed on an experimental trout planting program and a large-scale creel census. The major purposes of the census were: (i) to provide a quantitative description of the sport fishery, (ii) to establish a baseline of existing conditions so that future changes could be recognized and evaluated, (iii) to evaluate experimental trout plants, and (iv) to obtain biological data from angler-caught fish.

[1] Submitted for publication November 1965. This work was performed as part of Dingell-Johnson Projects California F-21-R and Nevada F-15-R, "Lake Tahoe Fisheries Study", supported by Federal Aid to Fish Restoration funds.

[2] Table 1 lists the common and scientific names of Lake Tahoe fishes.

Estimates of total catch, total use, and angler origin for 1962 have been published (Weidlein, Cordone, and Frantz, 1965). The present report describes relative angler use, success rates, species and size composition of the catch, additional total use and catch estimates, and related characteristics of the fishery.

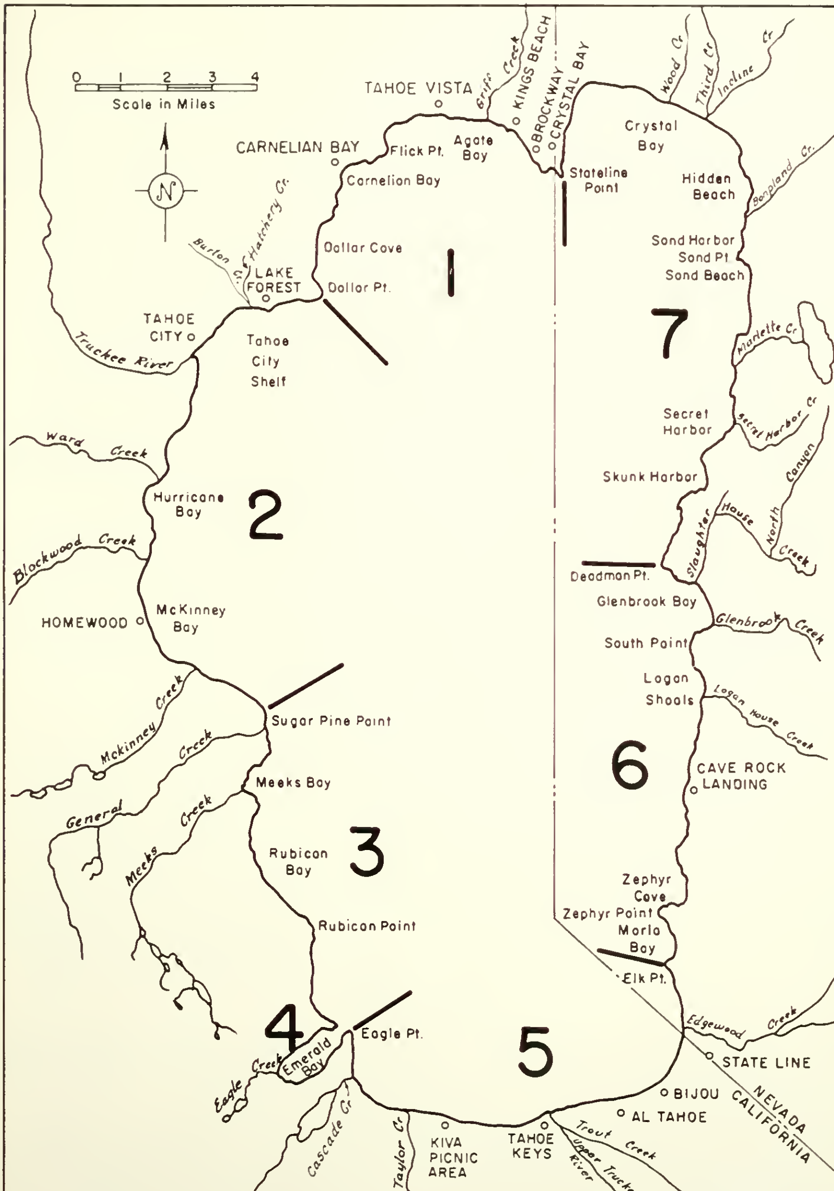

FIGURE 1. Map of Lake Tahoe, showing important landmarks.

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DESCRIPTION OF LAKE TAHOE

Lake Tahoe is a cold, extremely oligotrophic lake located at an elevation of 6,229 feet in the Sierra Nevada of California and Nevada (Figure 1). It averages 1,027 feet deep, has a maximum depth of 1,645 feet, and covers 123,300 surface acres. McGauhey et al. (1963) describe it in more detail.

HISTORY OF THE FISHERY

Lake Tahoe was once famous for its Lahontan cutthroat trout fishery, both sport and commercial. Juday (1907) conducted a brief study of Tahoe in 1904. His data suggest that sport and commercial catches approached 75,000 pounds in good years. He noted that lake trout were caught occasionally and mentions a 10-pounder caught near Glenbrook.[3]

During the 1920's or early 1930's, the fishery changed completely. As early as 1911, lake trout "were frequently seen at Tallac" (Snyder, 1917). Later, lake trout "were reported as fairly plentiful" (Kemmerer, Bovard, and Boorman, 1923). By 1938 Lahontan cutthroat had "practically disappeared" and the lake trout "flourished" (Curtis, 1938). Miller (1951) found "no verification that it [cutthroat trout] still exists in the lake" in 1948 and 1949. We believe that the cutthroat trout native to Lake Tahoe is extinct. Occasional cutthroat encountered are most likely planted fish of the Heenan Lake, California, strain. The Lake Tahoe sport fishery for wild trout is now clearly dominated by the lake trout.

LAKE TAHOE FISHES

Other than mountain whitefish, Lake Tahoe's game fish species are all introduced forms (Table 1).[4] The composition of the nongame fish fauna has not changed. The Bonneville cisco (*Prosopium gemmiferum*) was stocked in 1964, 1965, and 1966, but its status is uncertain (Frantz and Cordone, 1965).

FISHING REGULATIONS AT TAHOE

Tahoe fishing regulations differ from those at most other trout waters in Nevada and California. Before 1955 the regular trout season (May through October) was in effect. On January 1, 1955, a year-round trout season was put into effect. Changes since then have been minor and probably have not influenced catch statistics gathered by the project.

Tahoe game fishes may be taken only from 1 hour before sunrise to 2 hours after sunset. The bag limit is five trout, kokanee salmon, or whitefish in any combination and irrespective of weight and length.

METHODS

It was obviously impossible to census all Tahoe anglers. Some type of sampling program by boat or from shore was necessary. Hazardous flying conditions precluded census by airplane.

Nevada had been censusing at Cave Rock Public Boat Landing since 1954, so this phase of the census was continued. Here it was possible

[3] The first confirmed introduction of lake trout (known locally as "mackinaw") into Lake Tahoe was made in 1889 by the Nevada Fish Commission. According to Miller and Alcorn (1945), earlier plants may have been made in 1885.

[4] Fish nomenclature follows Shapovalov, Dill, and Cordone (1959).

TABLE 1

Lake Tahoe Fish Fauna

GAME FISHES

Coregonus williamsoni—mountain whitefish
Oncorhynchus nerka—kokanee salmon
Salmo trutta—brown trout
Salmo clarkii henshawi—Lahontan cutthroat trout
Salmo gairdnerii—rainbow trout*
Salmo gairdnerii regalis—royal silver rainbow trout†
Salvelinus fontinalis—eastern brook trout
Salvelinus namaycush—lake trout

NONGAME FISHES‡

Catostomus tahoensis—Tahoe sucker
Richardsonius egregius—Lahontan redside
Siphateles bicolor obesus—coarseraker tui chub
Siphateles bicolor pectinifer—fineraker tui chub
Rhinichthys osculus robustus—Lahontan speckled dace
Cottus beldingii—Piute sculpin

* A self-sustaining population; probably descendents from early releases of steelhead rainbow trout (*Salmo gairdnerii gairdnerii*) and Shasta rainbow trout (*Salmo gairdnerii stonei*). Kamloops rainbow trout (*Salmo gairdnerii kamloops*) were planted in recent years.
† Robert J. Behnke (personal communication) has doubts about the validity of this subspecies. Based on examination of museum specimens and a series collected during the present study, he believes that *S. g. regalis* represents introduced rainbow which assume a very silvery appearance in Tahoe's limnetic zone.
‡ The Lahontan mountain-sucker (*Pantosteus lahontan*) has been reported from Lake Tahoe, but was not collected during this study.

to census anglers who had completed fishing. A census by boat was initiated to determine if there were shore stations on the California side similar to Cave Rock, where use justified a census taker. From September through December 1960, each boat angler was asked where he launched or docked his boat.

Numerous, scattered access points were found on the California side, but the facility with the highest use accounted for only 13% of the total. Thus, for the months censused, and very likely for the remaining months, there were no locations where boat use justified a shore census station. We decided to continue the census by boat as the most efficient method of obtaining data representative of the entire lake.

During both censuses, only game fish were enumerated. A very few tui chubs, suckers, and crayfish (*Pacifastacus leniusculus*) were encountered in the creels.

Fishing method and time fished to the nearest quarter hour were recorded. We attempted to measure all game fish (fork length, unless otherwise stated) and made no selection on the few occasions when all fish could not be measured. Fewer weights were taken. To obtain monthly mean weights, missing weights for individual fish were estimated from length-weight relationships.

The "planted trout" category includes a variety of species and strains of rainbow and cutthroat trout planted throughout the census period from 1960 to 1963. No attempt is made to evaluate the individual plants or to assess the role of planted trout in a management program for Lake Tahoe. This will be the subject of a future detailed report. However, to better understand success and catch data the combined numbers of trout planted by month and year are given (Table 2). During this period, virtually all planted trout were yearling, "catchable-sized" fish, and most of those caught were captured within three months after release. Thus, their contribution does not represent natural production.

TABLE 2

Numbers of Trout Planted in Lake Tahoe *

Month	1960	1961	1962	1963	Years combined
January	--	--	--	--	--
February	-	--	--	--	--
March	8,041	--	--	--	8,041
April	5,970	28,260	--	14,981	49,211
May	3,800	15,071	12,345	--	31,216
June	10,534	15,863	216,811	--	243,208
July	--	--	--	15,755	15,755
August	25,831	27,230	17,800	98,368	169,229
September	106,823	172,141	--	--	278,964
October	--	--	--	--	--
November	--	--	--	--	--
December	--	--	--	--	--
Annual totals	160,999	258,565	246,956	129,104	795,624†

* All were yearlings except 11,949 (1.5%) two-year-olds, and 16,750 (2.1%) young-of-the-year. Includes both marked and unmarked fish. Excludes fish planted in tributary streams.
† Composed of 226,766 domestic fall-spawned rainbow; 369,758 rainbow from various wild strains; 157,841 Lahontan cutthroat; 40,748 Yellowstone cutthroat (*Salmo clarkii lewisi*); and 511 brown trout.

The presence of clipped fins or maxillaries permitted the separation of planted trout from wild trout, and enabled us to evaluate the lake's natural fishery. All unmarked trout were assumed to be from naturally-reproduced stock. For example, the category "rainbow trout", whenever used in this report, refers to unmarked and therefore wild rainbow trout. This is not entirely true, since 37,327 planted rainbow trout released in 1960 and 1961 were unmarked. However, all but 6,624 of these were planted in 1960, before initiation of the lakewide census. Since very few of these fish survive after a year of liberty, error from this source must be small. Many unmarked rainbow fingerlings were planted before 1960, but their survival is believed to be low, although supporting evidence is lacking.

Boat Census

Boat census [5] at Lake Tahoe began in September 1960, and terminated December 31, 1963. During this period there were four major variations in methods, as follows:

September 1960 through January 1961

One boat censused the California portion of Lake Tahoe. This area was divided into two sections, with Sugar Pine Point as the approximate mid-point between the north and south state lines (Figure 1). Starting points alternated between the north state line and Sugar Pine Point. The census taker moved in a counter-clockwise direction near shore, interviewing all anglers. We tried to census each day that weather permitted, but missed many days due to boat breakdowns. The census day began about 10:00 a.m. P.S.T., and continued until dark.

[5] The term "boat census" refers to the method of contacting anglers. It does not refer to a census of anglers fishing from boats ("boat anglers").

February 1961 through May 1961

During this period, the boat census was expanded to include the entire lake on a routine schedule. Again, only one boat was available. The lake was divided into three sections bounded by Stateline, Sugar Pine, and Elk points.

Censuses were scheduled on four weekend days and four weekdays per month. Alternate Saturdays and Sundays and staggered weekdays were selected. All major holidays were also included. If the weather was too rough to census, the missed day was made up as soon as possible, but only within the same month. All anglers encountered in the counter-clockwise trip around the lake were censused. The census usually began at 10:00 a.m. P.S.T., and the goal became a complete trip around the lake each census day.

Cave Rock was censused on the same days.

June 1961 through October 1961

The February-through-May schedule was maintained, but two boats were used except when they suffered mechanical breakdowns. A major change increased the number of starting points to four by adding Deadman Point and substituting Dollar Point for Stateline Point. The boats began censusing at opposite ends of the lake one day and rotated to the other two points on the next census day. The boats attempted to remain 3 to 5 hours apart to avoid censusing the same anglers too often. Boat-to-boat radios helped maintain this separation. Each census taker tried to cover the entire perimeter of the lake and to census all anglers encountered. When anglers were censused a second time, any additional information was added to that gathered at the first contact. A caudal fin clip identified fish previously examined. The census day started at 8:00 a.m. P.S.T. To speed the census, we counted but did not interview boat and shore anglers emanating from, or fishing from, the Cave Rock Public Boat Landing. Such counts started June 1 for boat anglers and July 16 for shore anglers.

November 1961 through December 1963

During this period, the boat census and Cave Rock census were conducted on different days. This permitted simpler and more direct calculations of lakewide statistics and reduced disturbance of anglers. The census schedule remained constant through 1962. In 1963, census effort was reduced to four weekend days (alternate Saturdays and Sundays) per month. Starting points, starting times, and the two boat censuses were retained. In 1961 and 1962, each angler's home town was recorded.

In 1962 and 1963, the lake was divided into seven areas, as follows (approximate shoreline distance in parentheses):

Area 1—Stateline Point to Dollar Point (8.9 miles)
Area 2—Dollar Point to Sugar Pine Point (12.7 miles)
Area 3—Sugar Pine Point to Eagle Point (8.6 miles)
Area 4—Emerald Bay (3.9 miles)
Area 5—Eagle Point to Elk Point (10.8 miles)
Area 6—Elk Point to Deadman Point (11.0 miles)
Area 7—Deadman Point to Stateline Point (16.8 miles)

When anglers fished in more than one area, or used more than one fishing method, their catch and effort in each stratum were apportioned to the areas and fishing methods as they reported them.

During all years of boat census, we recorded Cave Rock anglers and maintained a "use count" of those actively engaged in fishing when censused. Catch-per-unit of effort information was taken from all anglers observed, except anglers who could not be approached closely because of rough or very shallow water. They were counted only and their fishing method noted.

During boat census, hazardous water conditions sometimes made it impossible to examine each fish. Such fish were listed as "unknown" on the field form. No lake trout were involved, since they could be recognized even at a distance. The small number of "unknowns" were assigned to either planted or rainbow trout in proportion to the numbers of planted or rainbow trout taken for the month, angler category, and immediate area in question, to facilitate analysis.

Cave Rock Census

The Cave Rock census sampling level was about the same as that for the boat census. However, it was conducted on set days regardless of weather. Essentially the same information was taken. Data for 1959, all of 1960, and 1964 are available from Cave Rock.

CHARACTERISTICS OF THE ANGLERS

Angler Categories

From July 1960 through 1964, the combined Cave Rock and boat censuses interviewed 28,313 anglers, who fished 67,648 hours and caught 11,871 game fish. These anglers can readily be divided into four distinct categories: topline, deepline, shore, and pier anglers. Topliners generally use spinning tackle with monofilament line, but sometimes other types of non-metallic line. They usually fish in relatively shallow water near shore. Although most topliners troll, still and drift fishing are common. Deepliners use metallic line and fish close to the bottom, usually within half a mile but sometimes as much as 2 miles from shore. They normally use rods, but handlines are not uncommon. Those using handlines are known locally as "jerkliners".

Success rates in this report do not reflect relative efficiency exactly. Fishing time recorded for topline, shore, and pier anglers more closely approximates the actual time the bait or lure is "fishing" than time recorded for deepliners. Deepliners usually employ from 200 to 900 feet of line and are effectively fishing in lake trout habitat only when terminal tackle is close to the substrate. Much time is spent in achieving this goal.

The mean number of anglers per party for each angler category was obtained monthly from the boat census for the period September 1960 through October 1961. The weighted means for this period were 1.8 for topliners (range of monthly means: 1.5 to 2.7); 1.5 for deepliners (range: 1.2 to 1.8); 1.7 for shore anglers (range: 1.0 to 2.0); and 1.6 for pier anglers (range: 1.2 to 1.8). The means were remarkably uniform for months and categories. Deepliners fished alone more frequently than other anglers.

Origin by Angler Category

Weidlein et al. (1965) estimated total angler days for each origin area for each month of 1962. They found, "About one-fourth of these trips were made by local Tahoe-California anglers. In descending order, other significant areas of origin were the San Francisco Bay area (Region 3), central California (Region 2), Reno and Sparks, and the Los Angeles area (Region 5) . . ." Other areas were relatively unimportant.

Analyzing angler origin data by angler category revealed that most deepliners (almost 63%) lived on the California side of Lake Tahoe or in the Reno-Sparks area (Table 3). Apparently, anglers living close to Tahoe were more willing to buy the specialized deepline gear. Almost 35% of the topliners were local Tahoe-California anglers. The remainder were about equally divided among the San Francisco Bay area, central California, Reno-Sparks, and the Los Angeles area. These five major origin areas contributed similar numbers of shore anglers, although Reno and Sparks contributed the most because of the popularity of shore fishing at Cave Rock. The majority of pier anglers came from the four major California areas.

TABLE 3

Percentage of Angler Days by Angler Category for Each Origin Area, Lake Tahoe, 1962

Area of origin	Deepline	Topline	Shore	Pier
Region 1*—California (northern counties)	0.0	0.1	0.3	0.3
Region 2*—California (Central Valley)	9.1	19.9	11.1	19.5
Region 3*—California (Bay Area and Central Coast)	8.6	14.7	16.0	30.2
Region 4*—California (Fresno and vicinity)	1.7	1.5	2.0	2.2
Region 5*—California (southern counties)	1.6	9.3	11.3	14.3
Tahoe—California†	28.0	34.9	15.5	25.0
Tahoe-Nevada†	5.0	2.3	6.1	2.5
Reno and Sparks, Nevada	34.7	12.2	20.3	2.1
Carson City, Nevada	4.3	2.5	10.8	0.5
Other areas, Nevada	3.4	1.6	3.9	1.4
Other states and countries	0.6	0.9	2.7	2.0
	100.0	99.9	100.0	100.0

* Regions refer to California Department of Fish and Game administrative regions.
† Within 5 miles of the lake.

Angler Day by Angler Category

Cave Rock census data from 1961 through 1964 indicated that average time spent per fishing day varies among angler categories. Deepliners spent the most time per trip, with a 4-year mean of 4.8 hours. Topliners were next, with a corresponding value of 3.7 hours, while shore anglers had a mean of only 2.4 hours. Means were relatively uniform from month to month and year to year.

Adults Versus Children

From February 1961 through October 1961, numbers of adults and numbers of children under 16 years of age were tallied separately. Only 2.1% of all deepliners were children. In contrast, percentages of topliners, shore anglers, and pier anglers who were children were 15.1, 32.5, and 61.5, respectively.

RELATIVE USE

The number of anglers observed each census day was used to compare angler use within and between angler categories. These values were much less variable from month to month than angler hours for months with low use. Since the length of an angler day varies among categories, only rough comparisons among categories are possible, but variations within categories are accurate.

Combined 1962 and 1963 data revealed definite annual use patterns (Table 4, Figure 2). Deepline and topline use paralleled each other except that the former peaked in June and the latter in July and August. Both were much lower in October and November than in any other month. Winter use for these categories varied according to severity of the weather. Use by shore and pier anglers closely approximated each other, being high in June, July, and August and low in other months.

TABLE 4

Relative Angler Use: Mean Number of Anglers Counted Per Census Day By Month and Angler Category from Boat Census, 1962 and 1963 Combined

	Deepline		Topline		Shore		Pier		Shore & pier		All anglers	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent	No.	Percent
January	24.4	8.2	19.6	6.2	9.3	5.0	5.5	2.8	14.8	3.9	58.8	5.9
February	27.9	9.4	28.7	9.0	10.1	5.5	9.4	4.8	19.6	5.2	76.1	7.7
March	19.9	6.7	19.9	6.3	6.0	3.3	6.5	3.3	12.5	3.3	52.3	5.3
April	29.2	9.9	27.2	8.5	12.7	6.9	17.3	8.9	30.0	7.9	86.4	8.7
May	28.6	9.6	21.9	6.9	14.0	7.6	13.5	7.0	27.5	7.3	78.1	7.9
June	39.3	13.3	34.3	10.8	25.9	14.1	33.9	17.5	59.7	15.8	133.4	13.4
July	33.6	11.3	46.1	14.5	36.6	19.9	39.3	20.2	75.9	20.1	155.7	15.7
August	27.4	9.2	44.7	14.0	39.6	21.5	34.2	17.6	73.8	19.5	145.9	14.7
September	24.7	8.3	24.8	7.8	10.0	5.4	7.8	4.0	17.8	4.7	67.4	6.8
October	11.1	3.7	9.4	3.0	2.2	1.2	8.2	4.2	10.5	2.8	30.9	3.1
November	9.4	3.2	12.2	3.8	6.3	3.4	9.6	4.9	15.9	4.2	37.5	3.8
December	20.9	7.1	29.4	9.2	11.4	6.2	8.9	4.6	20.3	5.4	70.6	7.1
All year	24.9	99.9	26.9	100.0	16.1	100.0	17.2	99.8	33.3	100.1	85.1	100.1

Relative use per unit of shoreline in 1962 and 1963 was much lighter in Area 3 (Sugar Pine Point to Eagle Point) and Area 4 (Emerald Bay) than other areas (Figure 3). Use in Area 7 (Deadman Point to Stateline Point) was intermediate, while use in remaining areas was similar except for relatively heavy shore and pier use in Area 6 (Elk Point to Deadman Point) and Area 2 (Dollar Point to Sugar Pine Point).

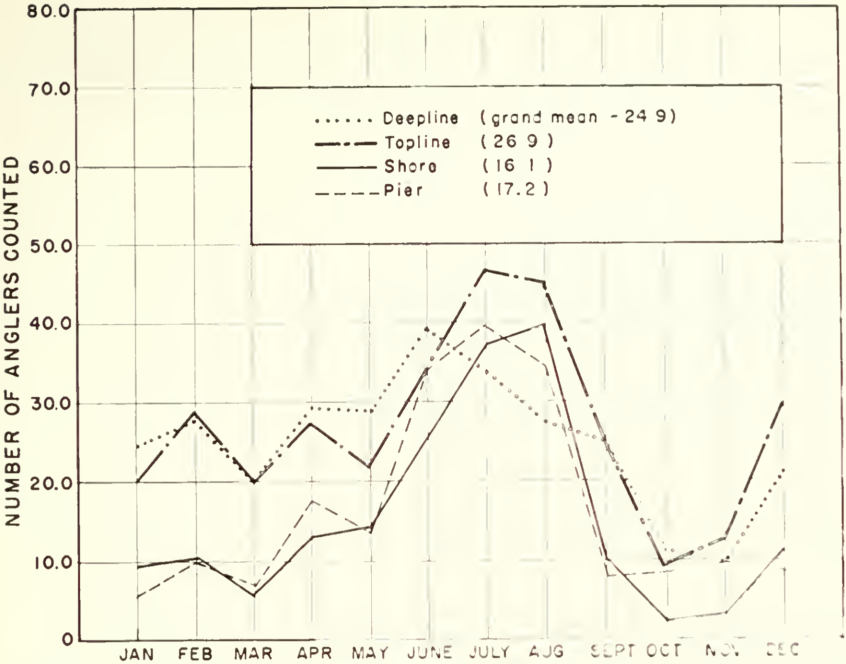

FIGURE 2. Mean numbers of anglers counted per census day by month and angler category; from boat census, 1962 and 1963 combined.

SPECIES COMPOSITION BY ANGLER CATEGORY

Lake trout made up about 99% of the deepline catch and about 35% of the topline wild fish catch, but were of minor importance in shore and pier catches (Table 5). Rainbow trout were the major wild game fish for all but deepline anglers. Of the wild trout, they constituted 60, 87, and 74% of the topline, shore, and pier catches, respectively. Whitefish were significant only to pier anglers, for whom they constituted about 22% of the wild fish catch. Planted trout contributed about 25, 76, and 42% to the topline, shore, and pier total catches, respectively. Brown trout constituted about 5% of the topline wild fish catch and contributed lesser amounts to other categories. Eastern brook trout were rarely caught. Kokanee salmon were taken in some years as they congregated for spawning.

PERCENTAGE OF SUCCESSFUL ANGLERS

Checks of completed efforts at Cave Rock permitted determination of anglers successful in catching at least one game fish (including planted trout) per angler day. Deepliners were more successful than other anglers (Figure 4). In all but 2 months, the percentage of successful deepliners ranged from 30 to 50%. Topline success was intermediate between success of deepline and shore anglers. From January through June, topline success was less than 30% but in the remaining months varied from 40 to 50%. Shore angler success in taking at least one fish was generally less than 20% the year around.

TABLE 5

Percentage Species Composition of Catch By Angler Category, Based on Catches Observed During 1962 and 1963 Boat Census, With and Without Planted Trout

Species	Deepline		Topline		Shore		Pier		All but deepliners		All anglers	
	With	Without	With	Without	With	Without	With	Without	With	Without	With	Without
Lake trout	98.9	99.0	26.4	35.1	0.9	3.7	1.2	2.1	12.6	23.4	55.9	72.6
Rainbow trout	0.6	0.6	44.2	59.1	20.9	86.8	42.7	73.7	35.9	66.5	18.2	23.6
Brown trout	0.4	0.4	3.7	5.0	0.2	0.7	1.2	2.1	2.0	3.7	1.2	1.5
Planted trout	0.2	--	25.2	--	75.9	--	42.1	--	46.0	--	23.0	--
Whitefish	--	--	0.4	0.5	2.1	8.8	12.5	21.6	3.4	6.3	1.7	2.2
Eastern brook	--	--	--	--	--	--	0.3	0.5	0.1	0.1	0.0	0.0
Totals	100.1	100.0	99.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.9

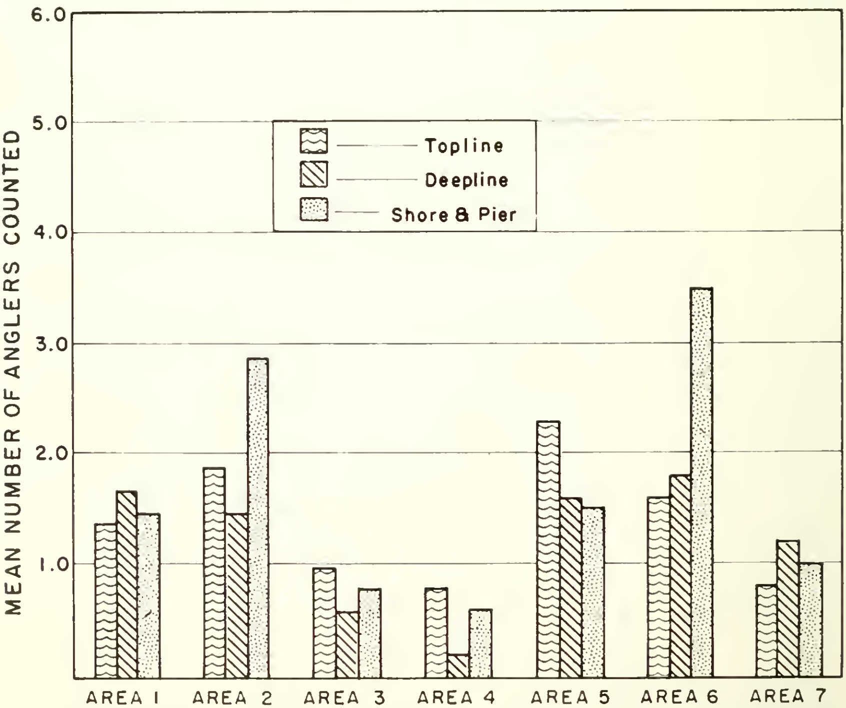

FIGURE 3. Annual mean numbers of anglers counted per census day by lake area; from boat census, 1962 and 1963 combined. Equated to Emerald Bay angler use; the number per 3.9 miles of shoreline.

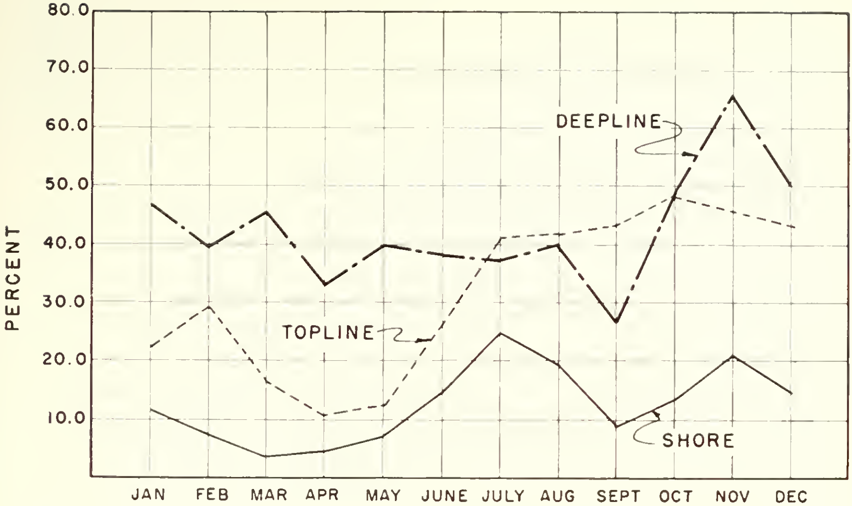

FIGURE 4. Percentage of successful anglers (those catching at least one game fish per angler day) checked at Cave Rock Public Boat Landing; 1962, 1963, and 1964 combined.

SUCCESS RATES BY ANGLER CATEGORY

Deepliners regularly had a much higher catch rate for wild fish than other anglers (Table 6). Their annual mean catch per angler hour was 0.209, compared with 0.082 for topliners, 0.065 for pier anglers, and only 0.036 for shore anglers. The addition of planted trout modified some of these values substantially. While deepline success remained essentially unchanged, topline success increased to 0.110 and pier and shore angler success rose to 0.113 and 0.145 fish per angler hour, respectively. If success rates were expressed in pounds of fish per angler hour, deepliners would be even more successful than other angler categories.

TABLE 6

Total Catch Per Hour by Angler Category From Boat Census, 1962 and 1963 Combined (Planted Trout Excluded)

	Deepline	*Topline*	*Shore*	*Pier*	*Shore and pier*	*All but deepline*	*All anglers*
January	0.140	0.122	0.021	0.041	0.028	0.086	0.111
February	0.205	0.061	0.010	0.036	0.021	0.050	0.112
March	0.262	0.061	--	0.042	0.023	0.047	0.140
April	0.212	0.100	0.045	0.117	0.077	0.090	0.141
May	0.254	0.082	0.048	0.196	0.106	0.094	0.168
June	0.251	0.070	0.053	0.055	0.054	0.061	0.138
July	0.146	0.066	0.039	0.025	0.033	0.048	0.077
August	0.140	0.042	0.026	0.023	0.025	0.032	0.058
September	0.148	0.064	0.024	0.054	0.036	0.053	0.096
October	0.225	0.116	--	0.045	0.036	0.084	0.142
November	0.351	0.166	0.063	0.192	0.126	0.144	0.201
December	0.266	0.142	0.018	0.106	0.053	0.109	0.161
All months	0.209	0.082	0.036	0.065	0.049	0.066	0.119

Success rates were lowest in the summer and highest in November for all but shore anglers. The low summer rate probably resulted from the influx of novice anglers. The November peak probably resulted from increased fish activity and or absence of all but relatively expert local anglers. An examination of success rates by species for each angler category helps to explain seasonal variations.

Topline Anglers

Success rates for these anglers for combined species were relatively uniform the year around except for a pronounced peak in October, November, and December (Figure 5). Variations among species were considerable.

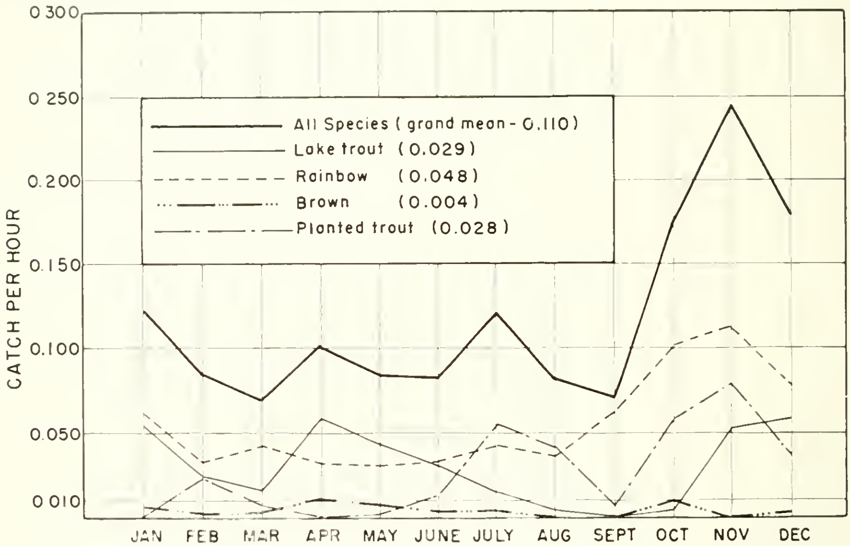

FIGURE 5. Topline catch per hour by species; from boat census, 1962 and 1963 combined (whitefish excluded: 0.001 in June and 0.002 in July).

Rates for rainbow followed the pattern for combined species in each year of the census. Mean monthly catches per hour were just under 0.050 for most months but rose to about 0.100 during October, November, and December.

Lake trout success rates had similar monthly trends each year from 1960 through 1963. Success was lowest (less than 0.020 fish per hour) in July, August, September, and October. We believe that warm water drives lake trout from the shallows at this time. Spawning in October may also influence success rates. Lake trout move into the shallows in November, December, and January, and greatly increase success rates. Success declines in February and March but rises again in April, May, and June. This increase probably occurs because lake trout become more active and pursue forage fish which concentrate in the shallows during these spring months.

Topliners took a few brown trout throughout the year; catch rates were usually less than 0.005 fish per angler hour. Whitefish were insignificant in the catch. Planted trout were taken, but apparently soon after release and in direct proportion to density of the plants.

Deepline Anglers

Deepliners fish specifically for lake trout and catch them almost exclusively. Monthly mean lake trout catches per hour followed definite trends, with only minor year to year variations (Figure 6). Although not representative of the entire lake, the 1960 and 1961 catches per hour followed the same pattern as those for 1962 and 1963. Rates

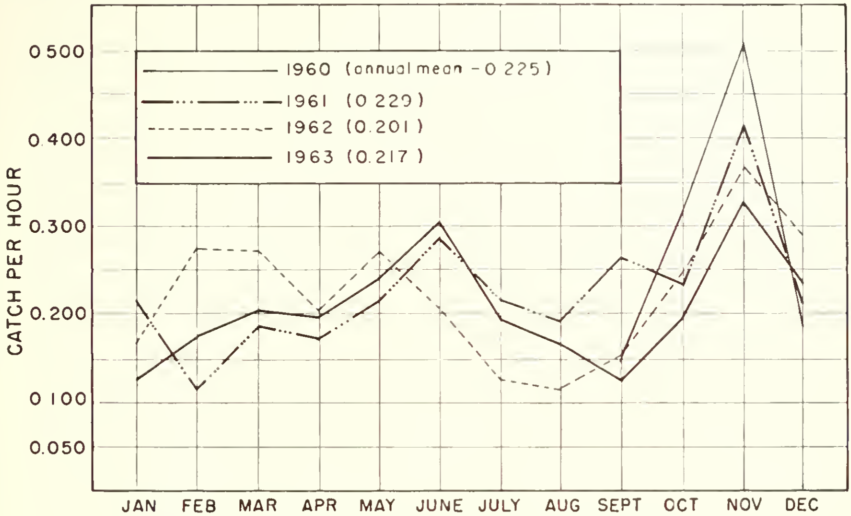

FIGURE 6. Deepline catch per hour for lake trout; from boat census.

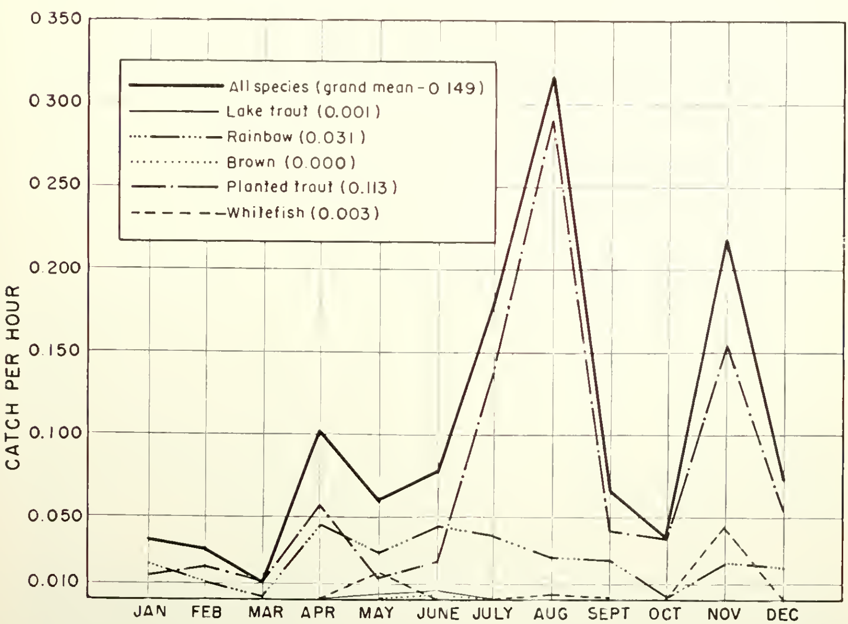

FIGURE 7. Shore catch per hour by species; from boat census, 1962 and 1963 combined.

generally exceeded 0.2 fish per hour from October through June, with a striking high of about 0.3 to 0.5 each November. Success rates for July, August, and September were generally less than 0.2. Some possible explanations for these patterns have been proposed already.

Shore Anglers

Shore anglers were the least successful of all Tahoe anglers in taking wild trout. Their success depended largely on planted trout (Figure 7). Catch per hour fluctuated greatly in response to the time and density of trout plants; the means in some months approached 0.3. Without planted trout, monthly means were generally less than 0.05 fish per angler hour.

Pier Anglers

Pier angler success was only slightly higher than that of shore anglers. They were less dependent on planted trout and more successful in taking rainbow and whitefish (Figure 8). Both rainbow and whitefish catches showed spring and autumn peaks, with the former approaching 0.15 fish per angler hour. Few lake trout were caught by shore and pier anglers. Planted trout contributed significant catches for relatively short periods following releases.

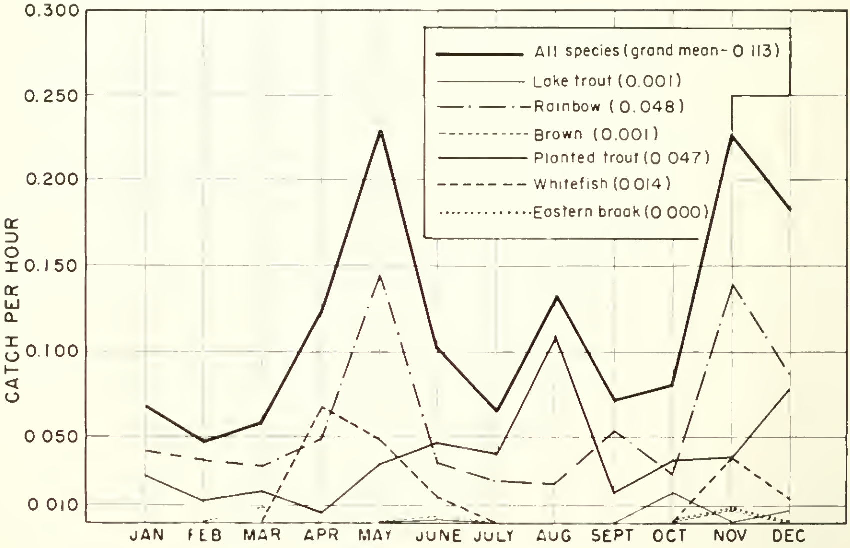

FIGURE 8. Pier catch per hour by species; from boat census, 1962 and 1963 combined.

The well defined spring and autumn increase in the whitefish catch occurred each year and is attributed to an inshore feeding migration in the spring and a spawning migration in the autumn. Large schools of whitefish are observed in the shallows at these times.

AREA SUCCESS RATES

Lake trout catches per hour by deepliners varied significantly among the seven lake areas (Table 7). Area 1 generally afforded the best fishing for the first 9 months of the year and close to the poorest for

the last 3 in both 1962 and 1963. The reasons for this are unknown. The relatively high success rates in Areas 1, 2, and 7 (annual means of 0.285, 0.218, and 0.208, respectively) and low rates in Areas 5 and 6 (0.160 and 0.169) indicated that deeplining was more productive in the northern half of the lake than in the southern half.

TABLE 7

Deepline Catch Per Hour for Lake Trout From Boat Census, 1962 and 1963 Combined *

	Area 1	*Area 2*	*Area 5*	*Area 6*	*Area 7*	*Area 1 rank*
January	0.172	0.144	0.059	0.208	0.121	2
February	0.340	0.109	0.086	0.135	0.192	1
March	0.449	0.299	0.167	0.264	0.221	1
April	0.367	0.272	0.204	0.135	0.104	1
May	0.320	0.235	0.219	0.189	0.321	2
June	0.332	0.239	0.266	0.224	0.188	1
July	0.231	0.136	0.039	0.076	0.288	2
August	0.276	0.111	0.018	0.089	0.203	1
September	0.179	0.178	0.091	0.117	0.101	1
October	0.242	0.229	0.247	0.322	0.119	3
November	0.143	0.464	0.441	0.287	0.323	5
December	0.142	0.419	0.129	0.363	0.404	4
All months	0.285	0.218	0.160	0.169	0.208	1

* Areas 3 and 4 eliminated because of low angler pressure.

Topline annual mean catches per hour for lake trout were lowest in Area 6 (1962 = 0.008, 1963 = 0.004) and highest in Area 5 (1962 = 0.053, 1963 = 0.043) for these years. Other areas had rates generally between 0.02 and 0.03 fish per hour. The conflict with deepline success is interesting, but again the reasons are obscure.

Toplining for rainbow trout was most productive in Area 7 in 10 out of 12 months (Table 8). Areas 5 and 6 tended to have the lowest overall success rates. There are no obvious explanations. Combined shore and pier data did not show the same high rainbow success rates in Area 7. They tended to be about average, with Areas 1 and 2 higher and 5 and 6 lower.

TABLE 8

Topline Catch Per Hour For Rainbow Trout From Boat Census, 1962 and 1963 Combined *

	Area 1	*Area 2*	*Area 5*	*Area 6*	*Area 7*	*Area 7 rank*
January	0.082	0.096	0.028	0.043	0.071	3
February	0.023	0.040	0.011	0.028	0.047	1
March	0.019	0.029	0.070	--	0.117	1
April	0.025	0.023	0.039	0.043	0.056	1
May	0.033	0.014	0.015	0.031	0.082	1
June	0.055	0.044	0.015	0.028	0.057	1
July	0.036	0.057	0.044	0.020	0.104	1
August	0.042	0.053	0.036	0.006	0.097	1
September	--	0.070	0.085	--	0.164	1
October	0.114	0.168	0.035	0.051	0.049	4
November	0.154	0.162	--	0.089	0.312	1
December	0.044	0.075	0.017	0.122	0.179	1
All months	0.046	0.057	0.032	0.031	0.106	1

* Areas 3 and 4 eliminated because of low angler pressure.

Whitefish fishing was best in Areas 1 and 2, which can be explained by the preponderance of piers there. Brown trout fishing did not appear to be better in one part of the lake than another.

Planted trout success rates tended to be highest in Area 6 (Table 9). Heavy trout plantings at Logan Shoals were probably responsible. Since success in Area 6 was among the lowest for all wild trout fisheries, fishing there was largely dependent on planted fish.

TABLE 9

Catch Per Hour For Planted Trout From Boat Census, 1962 and 1963 Combined *

	Area 1	*Area 2*	*Area 5*	*Area 6*	*Area 7*	*Area 6 rank*
January	--	0.014	--	0.009	--	2
February		0.014	--	0.030	0.050	2
March	0.034	0.011	--	0.008	--	3
April	--	--	--	0.014	0.019	2
May	0.019	0.014	--	0.005	0.026	4
June	0.043	0.029	0.010	0.043	0.019	1
July	0.008	0.025	0.032	0.189	0.032	1
August	0.349	0.045	0.009	0.283	0.123	2
September	--	0.010	0.014	0.024	0.044	2
October	0.026	0.006	0.030	0.024	0.207	4
November	0.041	--	0.039	0.196	0.129	1
December	0.010	0.045	--	0.090	0.080	1
All months	0.049	0.022	0.011	0.133	0.050	1

* Deepline effort excluded, and Areas 3 and 4 eliminated because of low angler pressure.

CAVE ROCK SUCCESS RATES

Cave Rock census, when coordinated with the boat census, made possible estimates of total use and catch in Lake Tahoe (Weidlein et al., 1965). Its value as an index area to follow trends in success and size of angler-caught fish depends largely on the amount of census effort and varies with the angler categories.

For all years of census, Cave Rock success rates for deepline-caught lake trout were lower than lakewide values (0.171 compared with 0.226 in 1961; 0.165 with 0.201 in 1962; and 0.191 with 0.217 in 1963). This is not surprising, since the bulk of Cave Rock anglers fished in Area 6, where values are lower than in most other areas (Table 7). The grand mean for combined 1962 and 1963 deepline catch per hour for lake trout was 0.169 in Area 6 and 0.175 at Cave Rock. This suggested that Cave Rock might provide a useful index of annual changes in the lake trout fishery.

However, in 1964 the mean catch per hour for deepline-caught lake trout dropped to 0.142. Frantz noted that several of the more consistently successful deepline anglers (and topliners also) were no longer using the Cave Rock Landing, while the number of inexperienced anglers increased. At low use levels, minor variations in fishing patterns can substantially influence trends and reduce their value. Hence, we suspect that the 1964 decrease at Cave Rock did not reflect the true trend in fishing success for the lake as a whole.

Monthly mean lake trout success rates of Cave Rock deepliners were much more variable than those of their lakewide counterparts and had no consistent trend (Figure 9). Fluctuations increased in magnitude under the one-day-per-week sampling in 1963 and 1964. Success rates

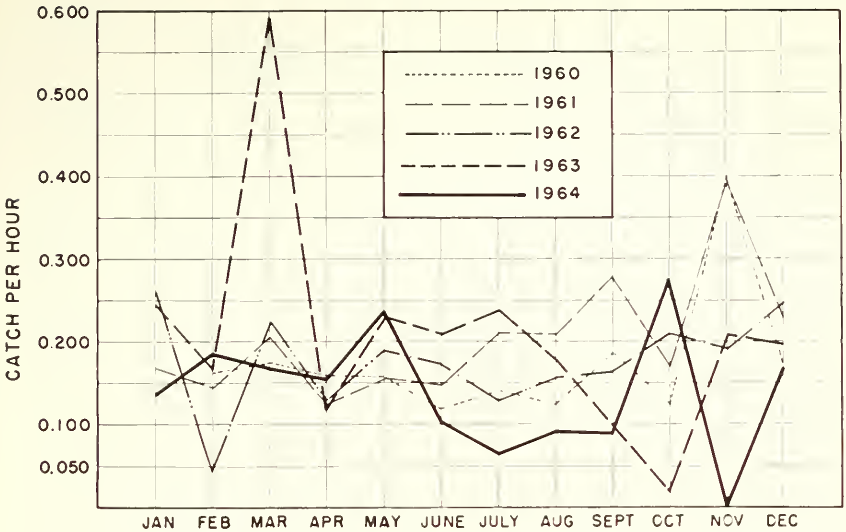

FIGURE 9. Deepline catch per hour for lake trout; from Cave Rock census (no deepliners checked in January 1960).

from the boat census were not significantly correlated with Cave Rock success rates for 1962 and 1963, but the 1961 correlation was significant at the 1% level ($r = 0.7681$, $t = 3.7941$, d.f. $= 10$). At Cave Rock 133 days were censused in 1961, compared with 106 in 1962 and only 55 in 1963. Thus, Cave Rock results reflected lakewide success well at $2\frac{1}{2}$-day-per-week sampling level, but not at lower levels. Hence, sampling at this level should provide a useful index of success, provided that daily angler use is sufficiently large to insure that changes in use by individual anglers do not significantly affect mean success rates.

Topline and shore angler catch rates were lower and more variable than lakewide values. Also, Cave Rock and Area 6 rates for these categories have been shown to be lower than those of other areas. Because of this, Cave Rock cannot be considered as an indicator of lakewide variations in success rates for topline and shore anglers.

GAME FISH LENGTHS AND WEIGHTS

Lake Trout

Length measurements from the Cave Rock census and boat census were combined, since t-tests indicated that monthly means differed significantly in only 4 of 38 months from September 1960 through December 1963. This also permitted certain comparisons, using 1960 and 1964 Cave Rock monthly and annual means.

From 1960 through 1964, the grand mean fork length was 18.5 inches (2.69 pounds), and the annual means varied only a half inch (Table 10). The use of t-tests indicated that the 1962 mean was significantly greater at the 1% level than the 1961 and 1963 annual means, but that means for the latter two years did not differ significantly. Because few or no lake trout were sampled in some months, 1960 and 1964

TABLE 10

Mean Lengths and Weights of Lake Trout Checked During Boat and Cave Rock Censuses *

Year	Cave Rock†			Boat census‡			Combined		
	Number	Length	Weight	Number	Length	Weight	Number	Length	Weight
1960	589	18.5	2.69	90	17.9	2.41	679	18.4	2.60
1961	716	18.4	2.60	835	18.4	2.60	1,551	18.4	2.60
1962	402	18.8	2.87	959	18.8	2.88	1,361	18.8	2.88
1963	301	18.2	2.64	694	18.3	2.57	995	18.3	2.57
1964	193	18.7	2.76	--	--	--	193	18.7	2.76
Totals	2,201	18.5	2.69	2,578	18.5	2.69	4,779	18.5	2.69

* All fish measured but not weighed. Calculated weights from length-weight relationship table substituted for missing weights.
† February 1960 through December 1964.
‡ September 1960 through December 1963.

were not included in these tests. Lake trout censused at Cave Rock and along the Nevada shore in 1959 averaged 19.5 inches (129 fish). Since lengths were taken to the next highest half inch, the sample size was small, and 4 months were not sampled, it is not valid to conclude that the mean length of angler-caught lake trout was greater in 1959 than in subsequent years.

Length frequencies of angler-caught lake trout were also similar each year (Figure 10). In 1961, 1962, and 1963 the mode was about 17.0 inches, while in 1960 it was 18.0 inches. In 1963, relatively fewer small and large fish were captured.

A definite monthly pattern of lake trout mean lengths was evident (Figure 11, Table 11). Except in 1960, the lowest mean length each year was recorded in October (about 17.0 inches). Lake trout spawn at this time, and the larger, mature fish apparently are not as vulnerable

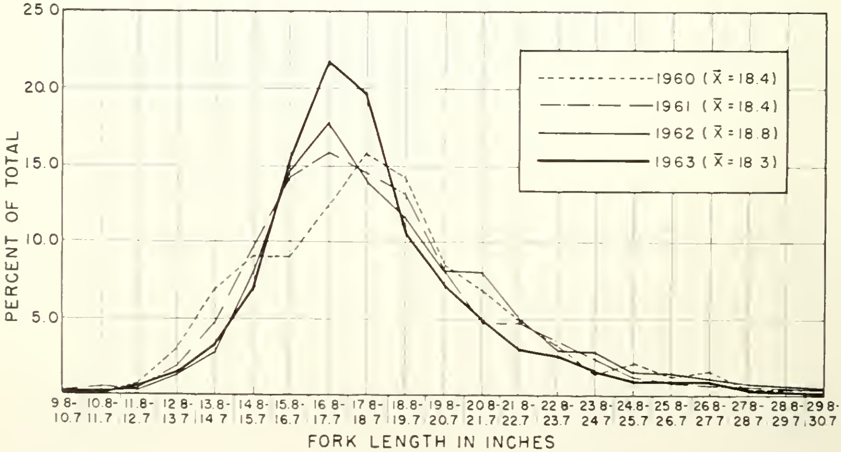

FIGURE 10. Size composition of angler-caught lake trout from Lake Tahoe; from both Cave Rock and boat censuses (15 fish larger than 30.7 inches not included).

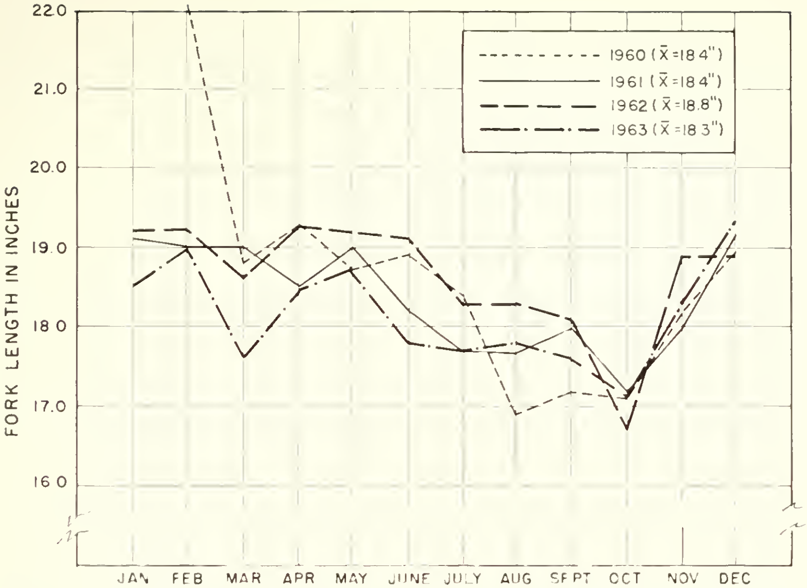

FIGURE 11. Mean lengths of angler-caught lake trout from Lake Tahoe; from both Cave Rock and boat censuses (no lake trout checked in January 1960).

to angling. Mean length increased abruptly in November and remained fairly constant (between 18.5 and 19.5 inches) until summer, when it gradually declined to about 18.0 inches. Few fish under 13 inches or over 28 inches were caught.

Analyses of variance for 1961, 1962, and 1963 indicated that these differences among monthly means were significant each year (1961: $F = 5.203$ with $F_{.01} = 2.25$; 1962: $F - 4.042$ with $F_{.01} = 2.25$; and 1963: $F - 4.219$ with $F_{.01} = 2.26$). Because of small samples or no samples in some months, 1960 and 1964 data were not included. The October mean was significantly lower than that of all other months in 1962 [6], 6 winter and spring months in 1961, and 5 winter and spring months in 1963. In 1961 and 1963, December means were significantly higher than means in most summer and autumn months.

Monthly mean lake trout lengths for each area had similar trends (Figure 12). Grand mean lengths were 18.3 inches for Area 1, 19.0 for 2, 18.7 for 5, 18.4 for 6, and 18.1 for 7. The use of *t*-tests indicated that lake trout caught in Areas 2 and 5 were significantly larger than those from Areas 1 and 7. Area 2 fish also were significantly larger than those caught in Area 6. With only small samples available, Areas 3 and 4 were not included in this analysis.

Topliners tend to catch larger lake trout than do deepliners. The grand mean of 256 fish caught in 1961, 1962, and 1963 by topliners was 19.8 inches, compared with a mean for deepliners of 18.4 inches. Topline fish averaged considerably larger (about 2 inches) in all months except July and August, when they were much smaller (Figure 13). This probably results from larger lake trout migrating inshore in the spring and autumn.

[6] Using Hartley's modification of Tukey's test (Snedecor, 1956; pp. 251–253), the months responsible for these differences were isolated (significance at 5% level).

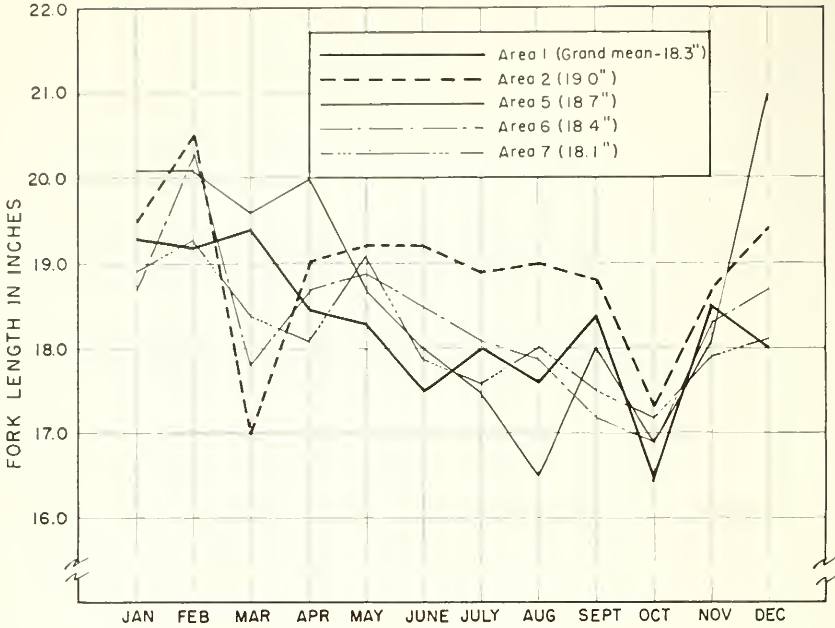

FIGURE 12. Mean lengths of angler-caught lake trout by area; from boat census, 1961, 1962, and 1963 combined.

Rainbow Trout

Boat census clerks measured 792 rainbow trout. The grand mean was 13.4 inches (1.36 pounds). Annual means were 12.6 (1.17) for 1961, 13.8 (1.45) for 1962, and 14.0 (1.52) for 1963. The significance of these differences among annual means cannot be judged because they could easily be due to sampling artifacts related to small sample size.

Smaller fish tended to be taken in the summer months (Figure 14). This may be due to increased use by shore and pier anglers, who take smaller rainbow than do topliners. Annual means of the former ranged from about 10 to 12 inches and the latter from about 15 to 16 inches.

A wide size range of rainbow was caught, and there is no dominant mode (Figure 15). Fairly uniform contributions were made by trout between about 5 and 20 inches.

Brown Trout

Fifty-nine brown trout were measured during boat census between 1960 and 1963. Their mean length was 17.6 inches (range 5.5 to 32.2 inches) and the mean weight 2.70 pounds. Most fish ranged between 10 and 24 inches, with no definite mode (Figure 16).

Whitefish

The mean length of 57 angler-caught whitefish checked by boat census clerks was 10.9 inches (range 5.8 to 18.8 inches), with a mode at 9.5 inches (Figure 17).

TABLE 11

Mean Lengths of Lake Tahoe Lake Trout Checked During Boat and Cave Rock Censuses

Month	1960			1961			1962			1963		
	Number fish	Mean length	Standard error	Number fish	Mean length	Standard error	Number fish	Mean length	Standard error	Number fish	Mean length	Standard error
January	--	--	--	147	19.1	0.3	55	19.2	0.4	107	18.5	0.2
February	11	22.1	1.8	60	19.0	0.5	35	19.2	0.5	90	19.0	0.3
March	31	18.8	0.4	59	19.0	0.4	112	18.6	0.3	16	17.6	0.6
April	93	19.3	0.4	187	18.5	0.2	146	19.3	0.3	61	18.5	0.3
May	153	18.7	0.3	216	19.0	0.2	155	19.2	0.2	164	18.7	0.2
June	84	18.9	0.4	312	18.2	0.2	247	19.1	0.2	244	17.8	0.2
July	63	18.4	0.4	172	17.7	0.2	152	18.3	0.2	95	17.7	0.2
August	29	16.9	0.7	97	17.7	0.3	64	18.3	0.4	76	17.8	0.3
September	103	17.2	0.3	149	18.0	0.2	97	18.1	0.2	20	17.6	0.4
October	43	17.1	0.3	58	17.2	0.3	47	16.7	0.3	19	17.1	0.4
November	30	18.2	0.6	39	18.0	0.4	68	18.9	0.3	41	18.3	0.5
December	39	19.0	0.5	55	19.2	0.5	183	18.9	0.3	62	19.4	0.4
All months	**679**	**18.4**	**0.1**	**1,551**	**18.4**	**0.1**	**1,361**	**18.8**	**0.1**	**995**	**18.3**	**0.1**

Trophy Fish

Lake trout larger than 20 pounds are rarely taken in Lake Tahoe. Probably less than three are caught annually. The generally accepted record is a $32\frac{3}{4}$-pound, 40-inch (total length) specimen caught by John Ernest Pomin in 1926.

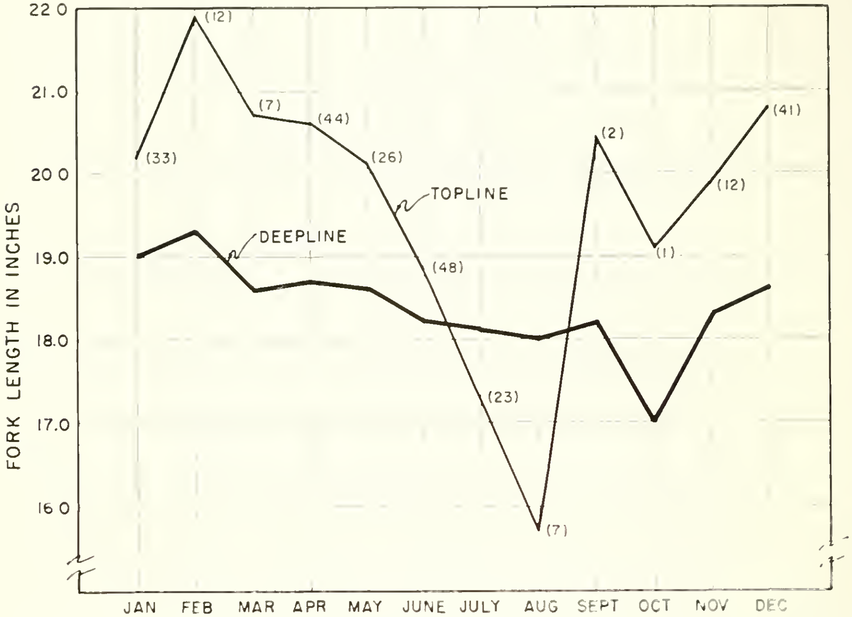

FIGURE 13. Mean lengths of topline- and deepline-caught lake trout from Lake Tahoe; from boat census, 1961, 1962, and 1963 combined (number of topline-caught fish in parentheses).

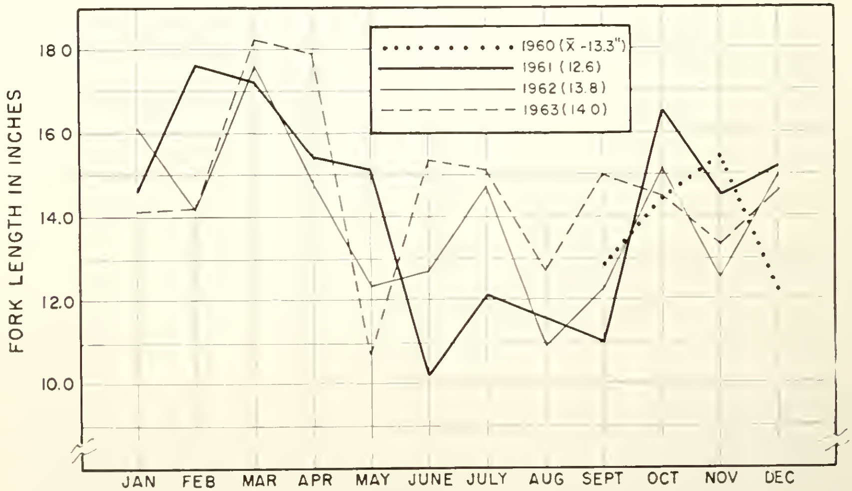

FIGURE 14. Mean lengths of angler-caught rainbow trout from Lake Tahoe; from boat census.

Equally rare are rainbow trout over 8 pounds and brown trout over 10 pounds. There has been no concerted effort to establish Tahoe records for these species. As far as we know, the record Tahoe rainbow is an 11-pound, 31½-inch (TL) fish caught by Peter Tallant in 1964. The record brown is believed to be a 16-pound, 5-ounce fish measuring 33 inches (TL) caught in 1964 by Ivan Ivanoff. We caught a 17.4-pound, 33.2-inch (fork length) brown in a gill net in 1962.

Whitefish and kokanee records are unknown. Kokanee in Tahoe achieve large size, probably close to 22 inches (FL). The largest whitefish taken in gill nets was 20.0 inches (FL), and weighed 6.4 pounds.

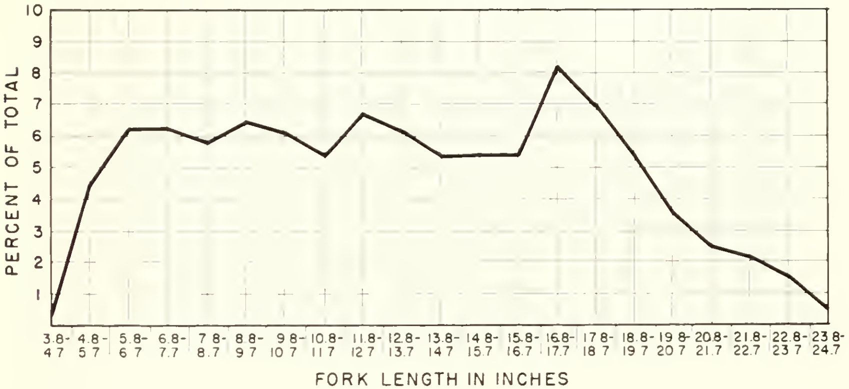

FIGURE 15. Size composition of angler-caught roinbow trout from Lake Tahoe; from boot census, 1961, 1962, and 1963 combined.

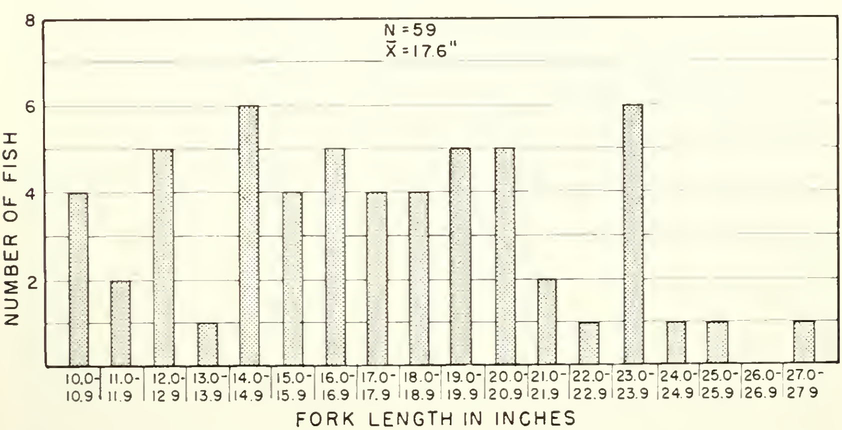

FIGURE 16. Size composition of angler-caught brown trout from Lake Tahoe; from boat census, 1960, 1961, 1962, and 1963 combined (5.5-inch and 32.2-inch specimens not included).

TOTAL CATCH AND USE ESTIMATES

Weidlein et al. (1965) estimated total Tahoe use and catch for 1962. The method involved: (i) calculations of the mean total angler hours for weekday and weekend days for Cave Rock anglers, (ii) expansion of these data to total monthly Cave Rock angler hours by multiplying

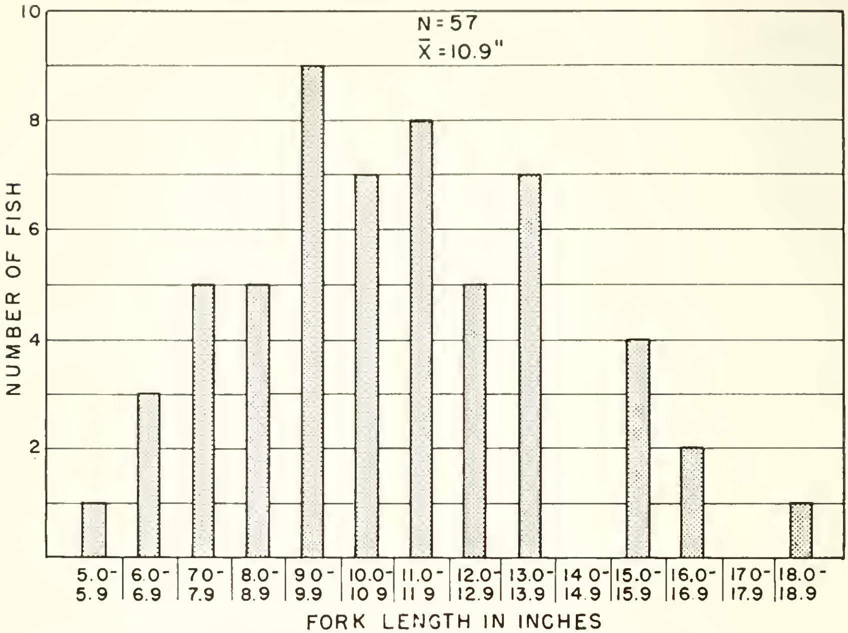

FIGURE 17. Size composition of angler-caught mountain whitefish from Lake Tahoe; from boat census, 1960, 1961, 1962, and 1963 combined.

the means by the total weekdays and weekend days, (iii) determination of the fraction of total lakewide anglers originating from Cave Rock for each month, (iv) estimation of total monthly Tahoe angler hours by dividing the fraction of Cave Rock anglers into total Cave Rock angler hours, and (v) multiplication of monthly total angler hours by monthly lakewide catch per hour for each species to estimate monthly total catches of each species.

With some modifications, these methods were used to obtain estimates of total use and catch for 1961 and 1963. Six months in 1961 (January, and June through October) did not have complete lakewide catch rate estimates. Only an approximation of total use and catch for January was possible, since census was restricted to the California portion of Tahoe. This was done by applying the fraction of Cave Rock anglers for January 1962 to January 1961 and assuming that the catch per hour for the California side represented the entire lake. For June through October, Cave Rock anglers were counted but not interviewed during boat census. By applying the fraction of Cave Rock anglers for each of these months to Cave Rock completed effort figures, it was possible to obtain estimates of the hours and catch that were missed. These were added to similar figures for the remainder of the lake to provide total monthly lakewide estimates. The high sampling level in 1961 [7] rendered this procedure sufficiently accurate for purposes of estimating total use and catch.

[7] About 9.5 percent of the estimated total Tahoe angler hours were actually checked during boat census, while 57.9 percent of the estimated total Cave Rock angler hours were actually checked at Cave Rock. Corresponding percentages for 1962 were 8.9 and 37.2, and for 1963 they were 6.4 and 23.7.

Since only weekend days were censused in 1963, it was necessary to modify the 1962 procedure. The mean weekend day angler hours at Cave Rock were multiplied by the number of weekend days to obtain estimated total monthly weekend angler hours. Monthly mean angler hours per weekday were found by multiplying the 1963 weekend day mean hours by the ratio of weekday to weekend day hours in 1962. Total Cave Rock monthly angler hours were then determined as in 1962. Total monthly use was estimated by dividing total use at Cave Rock by the fraction of Cave Rock anglers observed in the boat census. Even though all censuses were on weekends, this should not introduce bias, since weekend and weekday fractions were similar in 1962 (Weidlein et al., 1965).

Total catches were estimated by multiplying weekend catches per hour by total use, under the assumption that weekend and weekday fishing success rates were equal. Actually, from September 1960 through October 1961, weekday catch per hour was 0.208 while weekend day catch per hour was 0.180, even though weekend success was greater in 7 of the 14 months. Thus, 1963 catch estimates are probably biased downwards, and the change in procedure makes all estimates less precise than the 1962 ones.

The 1961 Lake Tahoe total use estimates were 123,795 angler hours and 35,582 angler days, and for 1963 these estimates were 133,217 angler hours and 40,093 angler days (Table 12). Examination of total use estimates for 1961, 1962, and 1963 again reveal the stable nature of the Tahoe sport fishery. While 1961 and 1963 values are lower than

TABLE 12

Total Lake Tahoe Angler Use Estimates

Month	1961		1962		1963	
	Total Tahoe angler hours	Total Tahoe angler days	Total Tahoe angler hours	Total Tahoe angler days	Total Tahoe angler hours	Total Tahoe angler days
January	12,068	3,345	2,317	890	7,235	1,995
February	4,768	1,284	2,045	932	6,891	1,899
March	3,416	810	3,024	1,051	2,295	650
April	6,900	1,800	16,153	6,221	2,904	784
May	13,430	3,478	10,741	3,392	13,124	3,725
June	24,256	7,002	35,671	12,097	18,857	5,433
July	23,488	7,466	28,434	9,585	19,779	6,140
August	21,895	6,623	18,571	5,814	32,089	10,876
September	5,658	1,580	10,118	2,723	17,398	4,868
October	3,712	1,052	4,442	1,464	2,009	550
November	2,283	633	2,488	639	4,123	1,238
December	1,921	509	10,143	2,924	6,513	1,935
Totals	**123,795**	**35,582**	**144,147**	**47,732**	**133,217**	**40,093**
Hours checked during boat census	**11,734.75**		**12,863.25**		**8,569.25**	
Hours checked during Cave Rock census	**11,126.50**		**7,100.25**		**5,386.50**	

the 1962 estimates, the differences are certainly within the limits which might be expected from sampling variability.

Deepline hours made up about 32.9% and topline hours 30.0% of the total estimated angler hours for combined 1961, 1962, and 1963 data. Shore and pier anglers made lesser contributions at 18.9 and 18.1%, respectively. Use in terms of angler days was divided fairly evenly among the four categories. Because of the longer average angler day for deepliners, they comprised only 21.8% of the total angler days. Contributions by topline, shore, and pier anglers were 26.5, 26.7, and 24.9%, respectively.

Lake Tahoe supports extremely light angler use. Annual mean use for the three years was about 1.1 angler hours per surface acre and 1,870 angler hours per shoreline mile. The light use per surface acre is related to game fish distribution and the lake's morphometry. Except for scattered rainbow trout and kokanee salmon, the limnetic zone is virtually devoid of fish life. Tahoes' fishes are restricted either to the littoral zone or are strongly bottom oriented, rarely descending to depths greater than 500 feet. Because of the U-shaped nature of Tahoe's basin, more than 75% (about 92,500 acres) of its surface is over depths greater than 500 feet and is essentially lost to fishing. Actually, deepliners rarely fish for lake trout in depths over 300 feet.

The 1961 and 1963 estimates of total catch and yield of lake trout were below the 1962 estimates (Table 13). The 1962 estimates of total weight taken and yield in pounds per acre were about 20% greater than those for 1961 and 1963. Because of changes in methods for 1961 and 1963, the significance of this cannot be judged.

TABLE 13

Estimated Catch and Yield of Lake Tahoe Wild Trout and Whitefish, 1961, 1962, and 1963

		Lake trout	Rainbow trout	Brown trout	Mountain whitefish	Eastern brook	All species
1961	Total catch	10,464	3,810	201	384	13	14,872
	Percentage of total	70.4	25.6	1.4	2.6	0.1	100.1
	Mean weight	2.60	1.17	2.13	0.40	0.40	--
	Total weight	27,206	4,458	428	154	5	32,251
	Percentage of total	84.4	13.8	1.3	0.5	0.0	100.0
	Yield (lbs./acre)	0.22	0.04	0.00	0.00	0.00	0.26
	Percentage of yield	84.6	15.4	0.0	0.0	0.0	100.0
1962	Total catch	11,967	4,125	269	287	5	16,653
	Percentage of total	71.9	24.8	1.6	1.7	0.0	100.0
	Mean weight	2.88	1.45	3.20	0.30	0.40	--
	Total weight	34,465	5,981	861	86	2	41,395
	Percentage of total	83.3	14.4	2.1	0.2	0.0	100.0
	Yield (lbs./acre)	0.28	0.05	0.01	0.00	0.00	0.34
	Percentage of yield	82.4	14.7	2.9	0.0	0.0	100.0
1963	Total catch	10,414	4,178	185	402	0	15,179
	Percentage of total	68.6	27.5	1.2	2.6	--	99.9
	Mean weight	2.57	1.52	2.63	0.50	--	--
	Total weight	26,764	6,351	487	201	--	33,803
	Percentage of total	79.2	18.8	1.4	0.6	--	100.0
	Yield (lbs./acre)	0.22	0.05	0.00	0.00	--	0.27
	Percentage of yield	81.5	18.5	0.0	0.0	--	100.0

The total harvest of wild trout was clearly dominated by the lake trout. Their mean annual yield was 0.24 pounds or 83% of the total yield of 0.29 pounds per acre. Lake trout comprised 70% by number and 82% by weight of the total game fish harvest.

DISCUSSION

Trends in the Lake Trout Fishery

Since lake trout became dominant in the Tahoe sport fishery in the 1930's, questions have been raised regarding their status. Deepliners with years of experience uniformly complain that lake trout are now smaller and fewer than in previous years. They maintain that lake trout formerly averaged about five pounds. Although agreement is not complete on when the change took place, the concensus is that it occurred sometime in the 1950's.

During this time, fishing pressure has presumably increased considerably, as a function of the increased human population. This, and the instigation of the year-round season in 1955, probably increased the lake trout harvest rate, which could cause a change such as this.

In addition, lake trout are vulnerable to overfishing (MacKay, 1963). Reasons put forth are characteristic slow growth and late maturation, plus the vulnerability of immature fish to winter fishing.

Available data on long-term changes in the Tahoe lake trout fishery were analyzed in this light. From May through September of 1938 and 1939 some local anglers measured and weighed 149 fish, which averaged 19.7 (FL) length and 3.09 pounds (range 13.0 to 29.0 inches), at the request of the California Division of Fish and Game (Curtis, 1938). In the summer of 1948 the Division obtained lake trout catch records from the Bijou Boat Landing (Miller, 1951). The mean weight of 688 fish was about 4.20 pounds (22.0 inches FL). Miller estimated the mean success rate at one lake trout per eight hours of fishing (0.125 fish per angler hour). Although the success rate is similar to present values, mean lengths and weights are higher than today's 18.5 inches and 2.70 pounds. However, fish measurements by anglers introduce the likelihood of exaggeration and the tendency to select larger fish for sampling.

A fishing guide at Lake Tahoe has maintained records of effort and catch since 1948. He is a deepliner who regularly fishes along the west shore between Dollar and Rubicon points from May through September. His annual fishing effort is relatively constant, and his notes are well kept. In 17 years he has averaged 99 fishing trips, 326 lake trout, and $870\frac{1}{2}$ angler hours annually. Mean catch per hour was 0.37 and mean weight of lake trout 3.21 pounds, both well above the lakewide values recorded from 1960 to 1964. During the 17 years, his success rate and mean size of lake trout have been stable, with a slight upward trend (Figure 18).

Data collected in this study give no concrete evidence of decline in success rates or mean length. A decrease in mean length of lake trout based on 1959 data and a slight decrease in Cave Rock success rates in 1964 are probably the result of sampling artifacts.

TABLE 14

Comparisons Between Lake Tahoe and Other Lake Trout Lakes [1]
(Arranged by Increasing Mean Depths)

Lake	Mean depth (feet)	Maximum depth (feet)	Surface area (acres)	Shoreline development[8]	Total dissolved solids (ppm)	Mean annual yield (lbs. acre)	Authority	Comments
Jackson Lake, Wyoming	?	100 to 500	25,540	?	?	4.44	Erickson (1965)	Healthy lake trout population; specimens up to 30 pounds; 80% of total catch is lake trout.
Cold Stream Pond, Maine	?	112	3,628	?	?	[5]0.25	DeRoche and Bond (1957)	Small lake trout population exposed to high exploitation rate (35% annually); future stocks endangered.
Merchant Lake, Ontario	?	?	960	?	?	2.8	Fry (1939), and Fry and Chapman (1948)	Maximum annual yield; probably higher than could be sustained.
Whitegull Lake, Ontario	?	?	128	?	?	1.9	Fry (1939)	Maximum annual yield; probably higher than could be sustained.
Lake Wabigoon, Ontario	?	?	9,088	?	?	1.1	Fry (1939)	Maximum annual yield from commercial fishery.
West Pike Lake, Minnesota	[2]27	120	714	?	[3]15	2.33	Schumacher (1961)	Data from three years of creel census; lake trout common.
Redrock Lake, Ontario	29	70	896	?	?	1.3	Fry (1939) and Fry and Chapman (1948)	Maximum annual yield; probably higher than could be sustained.
Trout Lake, Minnesota	[2]35	70	261	?	[3]15	2.50	Schumacher (1961)	Data from seven years of creel census; lake trout abundant; evidence of overfishing.
Clearwater Lake, Minnesota	[2]42	130	1,326	?	[3]17.5	0.22	Schumacher (1961)	Data from three years of creel census; lake trout common.
Lac la Ronge, Saskatchewan	42	138	352,000	11.6	149	[5]0.32	Rawson (1961b), and Rawson and Atton (1953)	Yield based on records of commercial fishery; main lake mesotrophic but Hunter Bay oligotrophic; each year 30- to 40-pound specimens taken.
Mountain Lake, Minnesota	[2]44	210	2,088	?	[3]24	3.03	Schumacher (1961)	Data from three years of creel census; lake trout abundant.
Cree Lake, Saskatchewan	47	197	285,440	13.6	22	0.87	Rawson (1959)	Yield based on records from 11 years of commercial fishing.
Lake Opeongo, Ontario	49	135	12,864	?	33	[5]0.34	Fry (1949), Fry and Kennedy (1937), and Fry and Chapman (1948)	Lake trout population being depleted when yield exceeds 0.5 pounds per acre per year.

Lake Simcoe, Ontario	56	115	179,200	?	?	0.14 to [5]0.28	McCrimmon (1956)	Annual yield could be exceeded without overfishing.
Wollaston Lake, Saskatchewan	57	318	509,110	14.7	35	0.55	Rawson (1959)	Yield based on records from 12 years of commercial fishing.
Fish Lake, Utah	75	117	2,500	?	[4]60	[5]3.57	Utah Dept. Fish and Game[6]	Yield based on mean annual catch recorded during creel census from 1959 to 1961.
Lake Athabaska, Alberta-Saskatchewan	85	105	1,952,039	6.8	58	[5]0.26	Rawson (1947)	Yield based on records from 20 years of commercial fishing; it might be increased.
Keuka Lake, New York	92	186	11,584	1.58	?	1.18	Royce (1943)	Considered the best lake trout fishery in New York.
Lake Nipigon, Ontario	180	?	1,107,200	?	99	0.5	Fry (1939)	Maximum annual yield from commercial fishery.
Lake Huron	195	732	11,726,400	3.1	117	[5]0.38	Baldwin and Saalfeld (1962)	Mean annual yield from commercial fishery before influence of lamprey predation (1889-1940).
Great Slave Lake, Northwest Territories	201	2,014	6,675,200	3.6	150	[5]0.42	Rawson (1949) and Kennedy (1956)	Yield from seven years of commercial fishing (1948-1951) following leveling off of the catch.
Waterton Lakes, Montana-Alberta	227	113	3,520	2.39	82	[7]0.43	Cuerrier and Schultz (1957)	Yield from estimated total sport catch in 1951.
Lake Ontario	261	738	1,812,800	2.8	155	[5]0.11	Baldwin and Saalfeld (1962)	Mean annual yield from commercial fishery before influence of lamprey predation (1913-1940).
Lake Michigan	276	869	14,336,000	2.6	118	[5]0.41	Baldwin and Saalfeld (1962)	Mean annual yield from commercial fishery before influence of lamprey predation (1911-1945).
Lake Superior	487	1,007	20,361,800	2.93	60	[5]0.21	Baldwin and Saalfeld (1962)	Mean annual yield from commercial fishery before influence of lamprey predation (1913-1955).
Lake Tahoe, California-Nevada	1,027	1,645	123,300	1.58	62	0.21	Present study	Mean annual yield from total catch estimates made in 1961, 1962, and 1963.

[1] All physical and chemical data confirmed in the literature but not necessarily found in authorities cited. In many instances we converted original data to acres and feet.
[2] Median depth.
[3] Total alkalinity (ppm).
[4] Methyl-orange alkalinity (ppm).
[5] Estimated or converted by authors.
[6] Unpublished data provided by Arnold Bangerter of the Utah Department of Fish and Game.
[7] Personal communication from J. P. Cuerrier.
[8] Ratio of the length of the perimeter of a lake to the length of the circumference of a circle whose area is equal to that of the lake (Hutchinson, 1957, p. 166). It is an index of the amount of shoreline irregularities.

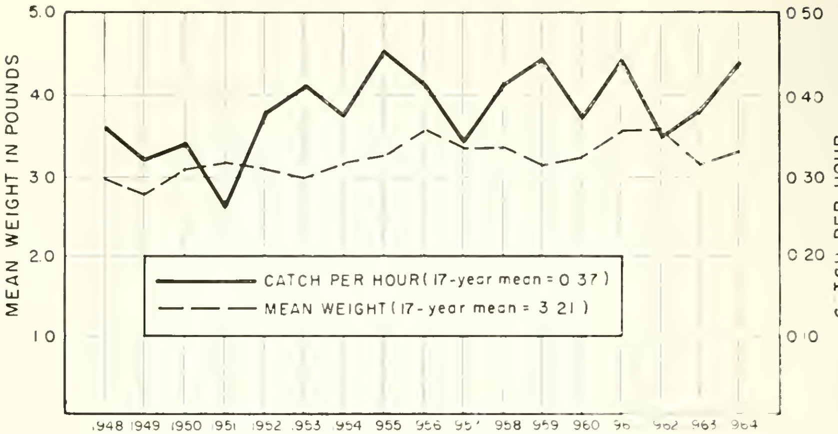

FIGURE 18. Annual mean weight and mean catch per hour of lake trout taken by a Lake Tahoe fishing guide.

Thus, the available quantitative information indicates a quite stable lake trout fishery and no need to change fishing regulations. It is recommended, however, that the detailed boat census in conjunction with the Cave Rock census be repeated in 5 to 10 years and results compared with those of the present study to re-assess the lake trout fishery.

Comparisons with Other Lakes

It is obvious from data presented in this report that lake trout dominate the Tahoe sport fishery. Unpublished gill netting data also reveal that the lake trout is the most abundant game fish by number and weight. To help determine if Tahoe is achieving its potential in providing a lake trout sport fishery, results were compared with those from other oligotrophic lakes (Table 14). Only those lakes which support abundant, self-sustaining lake trout populations were included.

The annual yield of lake trout in all lakes was generally low. Yield was less than half a pound per acre in lakes either over 100,000 acres or with mean depths over 100 feet. Yield of lake trout from Lake Tahoe was lower than from almost all other lakes in these categories.

This seems reasonable, in view of two of Tahoe's exceptional limnological characteristics. Goldman and Carter (1965) state, "On this basis the net primary productivity of the lake was 36.22 g c/yr/M^2 . . . Because of the extremely thick euphotic zone which averages about 60M, the productivity per unit volume (1.65 mg c/day/M^3) is very low and places Tahoe among the ultra-oligotrophic lakes of the world." Tahoe's mean depth of 1,027 feet (313m) is fifth greatest among the world's lakes and is most relevant to potential production. Rawson (1955) hypothesized that mean depth was a dominant factor in the productivity of large lakes, with productivity being inversely related to depth.

By dividing mean depth by total dissolved solids Ryder (1965) derived a "morphoedaphic" index which adequately estimated fish production for north-temperate lakes. Because of its great size and depth Tahoe has many similarities to Ryder's north-temperate lakes. The

index was lower for Tahoe than for any of the 33 lakes described by Ryder. Using his equation, Tahoe's potential fish production approximates 0.50 pounds per acre. Since the mean annual yield for all game fish was 0.29 pounds per acre and there is a relatively abundant but lightly exploited mountain whitefish population, Lake Tahoe could be close to achieving its potential production. However, caution is advisable in applying information on other waters to a lake like Tahoe, which has so many unusual features.

In addition, there is evidence indicating that a substantial increase in the yield of Lake Tahoe game fishes may be possible. First, if the historical records of cutthroat harvest are reasonably accurate (about 75,000 pounds caught in one year of record, for a yield of 0.60 pounds per acre), then Tahoe's potential may be twice that of the present yield. Second, Tahoe's vast limnetic zone contains very few fish. It should be possible to utilize the potential productivity of this area to augment game fish yield. For example, under proper management an open-water game fish like the kokanee salmon might directly provide fishing in the limnetic zone. Finally, Tahoe's forage fishes, because of their distribution patterns, are not well suited as food for the lake trout. Introductions of *Mysis relicta* and the Bonneville cisco were designed to fill this gap and thereby increase lake trout yield (Linn and Frantz, 1965; Frantz and Cordone, 1965).

SUMMARY

1. Lake Tahoe is a large, deep oligotrophic lake which once supported a popular sport and commercial fishery for Lahontan cutthroat trout. The fishery is now dominated by lake trout. Fishing was considered poor and this led to a joint California and Nevada study beginning in mid-1960. Creel census was a major segment of this program.
2. The census consisted of a coordinated check by boat of anglers around the entire perimeter of the lake and a check of anglers utilizing the Cave Rock Public Boat Landing. The census provided information on success rates, species composition, lengths of fish caught, and estimates of total use and catch.
3. Lake Tahoe anglers can be divided into four major categories: deepline, topline, shore, and pier anglers. Each had a distinct success rate and catch composition.
4. In terms of the lake's natural fishery, deepliners were the most successful anglers, followed by topliners, pier anglers, and finally shore anglers. The mean deepline success rate was about 0.2 fish per hour and about 99% of the fish caught were lake trout. Topliners averaged about 0.1 fish per hour and took a mixed bag of rainbow, lake, and brown trout. Pier anglers averaged about 0.06 and shore anglers 0.03 fish per hour. The former took rainbow and whitefish primarily, while the latter caught mostly rainbow trout. Planted trout contributed heavily to shore and pier success rates shortly after release.
5. The mean length of lake trout in the creel was about 18.5 inches (FL), with a mean weight of 2.69 pounds. The smallest lake trout were taken in October, coincident with the spawning season.

6. Total use and catch estimates were obtained for 1961 and 1963, using the methods described by Weidlein et al. (1965) for 1962 data. Annual mean angler use approximated 1.1 angler hours per surface acre. Mean annual lake trout yield was 0.24 pounds per acre. Lake trout made up 83% of the total yield.
7. Present data on the lake trout sport fishery, when compared to what limited historical data are available, gave no evidence that overfishing was taking place. Thus, no recommendations for changes in the lake trout regulations are made.
8. Evidence is presented which indicates that Lake Tahoe is close to achieving its potential game fish production with existing species. However, other evidence suggests that substantial increases in yield are possible if new forage organisms become established. Yield might also be increased under a suitable kokanee management program.

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FALL AND WINTER FOOD OF CALIFORNIA QUAIL IN DRY YEARS[1]

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Fall-winter diet of California quail, *Lophortyx californica*, was studied on the San Joaquin Experimental Range near O'Neals, California during November, December, and January of 1960–1963. Results were compared with a 1937 study in the same area.

Crops were collected from 376 California quail during the regular hunting seasons. They were grouped by month, and 171 chosen at random and analyzed. Diet components were reported by month and by year, and separated into seeds and leafage.

Important differences between current results and results of the 1937 study are shown and discussed. Varying weather conditions and resultant botanical composition caused wide variations in quail diet. The year 1937 and preceding years were wet; the period 1960–1963 was rather dry. In 1937, seed of filaree and turkey mullein formed more than 50 percent of quail diet in November and December, but made up only 6% in the 3-year period 1960–1963. Filaree was abundant in both periods, but early rains in 1960–1963 caused general plant germination that reduced availability of this seed. Turkey mullein was very scarce in 1960 and 1961 and seed was not available.

Far more green leafage was taken in November and December of 1960–1962 than in 1937. This was a result of earlier rains, general plant germination, and availability of green material in 1960–1962. Other important differences are discussed.

INTRODUCTION

Little is known about the seasonal diet of California quail. A study of quail food on lower foothill rangeland was done in 1937 on the San Joaquin Experimental Range near O'Neals, California, and reported by Glading, Biswell, and Smith (1940). Our study in the same area (1960–1963) indicated a very different fall-winter diet composition.

These differences are attributed to variations in weather conditions and availability of certain food plants. The earlier study was done in a wet year preceded by wet years, while the present study is based on collections in a series of dry years. Weather has a great influence on annual-plant rangeland and results in important changes in food items available for quail.

THE STUDY AREA

The San Joaquin Experimental Range includes more than 4,600 acres of rangeland in Madera County, California. It is fairly representative of the lower foothills of the western slope of the Sierra Nevada.

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Annual rainfall is about 19 inches, with extremes from 10 to 32 inches recorded since 1934. A Mediterranean-type climate, long dry summers and cool wet winters, and a shallow mantle of soil of granitic origin create favorable conditions for annual plants. Scattered brush, trees, and rock outcrops afford good quail cover (Glading et al., 1940).

The herbaceous vegetation consists almost entirely of annuals. These plants usually produce a heavy seed crop, the principal source of food for quail in fall and early winter. A list of plants in the area was prepared by Buttery and Green (1958). Among the most abundant species are broad-leaf filaree (*Erodium botrys*), soft chess (*Bromus mollis*), foxtail fescue (*Festuca megalura*), and ripgut brome (*Bromus rigidus*). Bur clover (*Medicago hispida*) is scarce and a very minor item in quail diet. However, in other grassland areas this species is an important food (Sumner, 1935).

For several years before and during the current study, the area was used for intensive, long-term research on grazing management of annual rangeland. Grazing use was moderate on the entire area during these studies.

METHODS OF COLLECTION AND ANALYSIS

Quail were collected for study during the regular hunting season, generally late October to early January. The crops of 376 quail were collected and grouped by month of collection; then 171 were selected at random for analysis at the California Department of Fish and Game Wildlife Investigations Laboratory. Each month from 8 to 30 crops were analyzed, the smaller number occurring in January.

Contents were analyzed by standard procedures. Frequency of occurrence of each item was tallied and quantity measured by water displacement in a graduated cylinder. Volumes were converted to percentages and summarized by the "aggregate percentage method" described by Martin, Gensch, and Brown (1946).

TABLE 1

Fall-Winter Quail Diet in 1937 and 1960–63 *
San Joaquin Experimental Range

Food item	1937	Fall-winter 1960–1961	Fall-winter 1961–1962	Fall-winter 1962–1963	3-year mean 1960–1963
Seeds		Percentage by volume of total diet			
Lotus strigosus	T†	53	39	4	32
Quercus spp. (acorns)	20	11	0	33	15
Lotus americanus	3	11	9	20	13
Lupinus bicolor	2	3	21	5	10
Eremocarpus setigerus	25	T	1	7	3
Trifolium spp.	12	T	1	3	1
Erodium botrys	26	5	4	1	3
Lupinus spp.	T	7	2	1	3
Green leafage	1	10	20	23	18

* Data collected from November-January, 1960-1963. Information for 1937 based on Glading et al. (1940), November and December only.
† Trace.

RESULTS

During the study years (1960–1963), 11 plant species formed 98% (by volume) of the fall diet; 41 different species made up the remaining 2%. Seeds comprised 82% of the diet; green leafage contributed 18% (Table 1). For the 3-year average, strigose lotus (*Lotus strigosus*) seed was the number one food item, furnishing more than 30% of the fall diet. Acorns, principally blue oak (*Quercus douglasii*), contributed 15%. Spanish clover (*Lotus americanus*) and lupines, mainly (*Lupinus bicolor*), contributed about 13% each. Of the green leafage, forbs furnished 12% of the diet; grass and clover about 3% each.

Glading et al. (1940) found that quail took quite different foods from the same area in November and December 1937 (Table 1). Seed of filaree, the most important food item, comprised 26% of the diet; turkey mullein (*Eremocarpus setigerus*) seed, furnished 25%. These two species in 1960–1963 comprised only 3% each. Strigose lotus seed appeared only as a trace in 1937, but was the most important food item in 1960–1963. Amounts of green leafage taken also differed considerably, with 1% in 1937 compared with 18% during 1960–1963.

Experimental Range rainfall records (Table 2) for the study years indicate some reasons for differences in diet. A 2- to 3-week lag is apparent between the first germinating rain and appreciable intake of (1960). During the drought years of 1959 and 1960, the percentage of grass on the range declined from 57 in 1959 to a low of 25 in 1960, green leafage. A germinating rain is the first effective rainfall, usually one-half to one inch, which brings on general germination of annual-plant seed. In 1960 and 1961, the first germinating rains occurred November 6 and 20, respectively. There was no appreciable use of green leafage until early December (Table 3). Germinating rain occurred on October 14 in 1962, and use of green leafage began early in November. In 1937, germinating rain did not fall until December 9. Very little leafage appeared in the quail diet in November and December.

TABLE 2

Monthly Rainfall, in Inches, During 1937–38 and 1959–63 San Joaquin Experimental Range

Weather year	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Total
1937–38	0.00	0.03	0.50	(9)* 6.22	6.00	7.74	8.70	2.69	0.02	0.00	0.19	0.00	32.09
1959–60	(19) 3.70	T†	T	0.36	2.35	4.68	1.98	2.38	0.08	0.00	T	0.00	15.52
1960–61	0.08	0.88	(6) 4.08	0.88	2.16	0.94	1.80	0.67	0.76	0.10	0.06	0.08	12.50
1961–62	0.02	0.10	(20) 3.32	1.90	2.61	10.04	2.38	0.21	0.06	T	0.06	T	20.68
1962–63	0.14	(11) 1.47	0.12	1.26	3.48	4.04	4.13	4.75	0.52	0.10	0.00	T	20.04

* Date of first germinating rain.
† Trace.

TABLE 3

Green Leafage in Quail Diet, During 1937 and 1960–63 *
San Joaquin Experimental Range

Fall and winter season	Crops analyzed Nov.	Dec.	Jan.	Date of first germinating rain	Type of leafage	Percentage by volume of total diet Nov.	Dec.	Jan.	Average
1937	8	5	0	Dec. 9	All	2.2	0.0		1.1
1960–61	18	20	19	Nov. 6	Forbs†	0.4	6.0	14.5	7.0
					Clover	0.0	4.5	0.7	1.8
					Grass	T‡	1.3	1.2	0.9
					Total	0.4	11.8	16.4	9.7
1961–62	15	30	13	Nov. 20	Forbs	T	9.5	24.7	10.4
					Clover	0.0	3.2	27.7	7.8
					Grass	T	2.6	2.3	1.9
					Total	T	15.3	54.7	20.1
1962–63	23	25	8	Oct. 14	Forbs	7.0	18.5	48.0	18.9
					Clover	T	T	0.0	T
					Grass	9.2	0.2	4.5	4.5
					Total	18.2	18.7	52.5	23.4
3-year average 1960–1961 through 1962–1963	56	75	40	...	All	6.2	15.3	41.2	17.7

* Data collected from November-January, 1960-63; 1937 information from Glading et al. (1940) for November and December only.
† Includes filaree.
‡ Trace.

Another influence of rainfall is its effect on botanical composition of the range. During extended periods of similar weather, certain types of plants are favored. Recent examples on the study area were reported by Reppert and Duncan (1960) and Duncan and Reppert then began increasing again (Table 4). During the same period, the percentage of total broadleaves (forbs), principally filaree, increased from 40 in 1959 to 74 in 1960, then decreased to 40 again in 1962. Herbage composition figures for 1959–1962 in Table 4 are from four unfertilized range units in a current grazing management study. Each unit is extensively sampled in the same manner every year. These ranges are representative of a much larger area of the Experimental Range where quail crops were collected.

There is a good relationship between availability and use by quail of acorns, turkey mullein, and green leafage. When acorns were available, quail used them readily. This is also true of filaree seed, except that its use is related to the first germinating rain and has little to do with the percentage of filaree in the total plant community. This desirable food plant is a prolific seed producer. With the first germinating rain, many of these seeds burrow into the ground in the manner described by Glading et al. (1940) and are lost as a food source. First rains also encourage new plant growth that makes ungerminated filaree seeds more difficult for quail to find. The first germinating rain in 1937 occurred on December 9. Filaree seeds were available over a long period and were heavily used by quail. In the 1960–1963 period, however, germinating rains occurred much earlier and filaree seed formed only a small part of the fall diet.

TABLE 4

Herbaceous Species Composition, San Joaquin Experimental Range 1937 and 1959–62

Year	Percentage grass	Percentage grass-like	Percentage broadleaves				
			Filaree	Clover	Other legumes	Other broad-leaves	Total
1937	52	1	31	1	1	11	47
1959	57	3	38	1	2	1	40
1960	25	0	63	1	3	9	75
1961	25	0	55	2	1	6	65
1962	56	4	22	8	2	8	40

It is also apparent that quail feed selectively, judging from their heavy use of strigose lotus, Spanish clover, and bicolor lupine. During 1960–1963, seed of these plants contributed over 50% of the fall-winter diet, but these species made up only 2% of the total plant composition of the range.

Strigose lotus comprised 53% of fall quail diet in 1960, even though it made up under 1% of the total plant composition. A bumper crop was observed and old-timers in the area commented that this was the most strigose lotus they had ever seen. It decreased in abundance during 1961 and was scarce in 1962. Much of the seed eaten in 1961 was probably a carry-over from the 1960 bumper crop. Strigose lotus contributed little to the diet in 1962. Most 1960 seed was probably exhausted and little was produced in 1961 or 1962.

Only a trace of strigose lotus appeared in quail crops analyzed for Glading's 1937 study. There are two possible reasons. (i) Weather was unfavorable for production of strigose lotus before and during his study. Rainfall was well above normal (Table 2). This species thrives on "scabby", rough lands which are usually south slopes. In wet years, the plants are crowded out by species better adapted to moist conditions. (ii) The other possibility is that quail taken had fed largely on better range sites not producing this species. The most likely explanation appears to be a combination of the two.

The variation between clover (*Trifolium* spp.) in the diet in 1937 and 1960–1963 (Tables 1 and 5) is simply explained. For good growth, clover needs moisture late in the growing season, and this was not available in 1960–1963. The small size of clover seed is another factor. Early germination of new plants during the 1960–1963 period made seeds harder for quail to find than in 1937.

Much the same may be said for turkey mullein. It makes most of its growth after other annuals have died, and does best when soil remains moist after other annuals have matured. Turkey mullein was scarce in 1960 and 1961 (dry years) and seed simply wasn't available. The year 1962 was somewhat wetter and there was noticeably more turkey mullein (although still not a heavy stand). Quail diet (Tables 1 and 5) reflected this.

TABLE 5

Seeds in Quail Diet During 1937 and 1960–63 *
San Joaquin Experimental Range

	November	December	January	Average
	Percent by volume of all food			
1937				
Acorn fragments	8.5	31.6		20.0
Lotus strigosus	0.0	0.0		0.0
Lotus americanus	6.5	T†		3.2
Lupinus bicolor	2.0	2.4		2.2
Erodium spp.	17.6	34.2		25.9
Trifolium spp.	14.0	10.2		12.1
Eremocarpus setigerus	29.3	21.6		25.4
1960–1961				
Acorn fragments	13.5	11.3	7.6	10.8
Lotus strigosus	17.0	70.1	69.3	53.1
Lotus americanus	33.8	1.0	T	11.0
Lupinus bicolor	8.4	0.5	0.1	2.9
Erodium spp.	15.8	T	0.0	5.0
Trifolium spp.	T	T	T	T
Eremocarpus setigerus	T	T	T	T
1961–1962				
Acorn fragments	0.0	0.0	0.0	0.0
Lotus strigosus	11.8	49.8	43.5	38.6
Lotus americanus	27.7	3.5	0.5	9.1
Lupinus bicolor	21.3	28.5	1.3	20.6
Erodium spp.	16.0	T	T	4.1
Trifolium spp.	0.5	1.6	T	1.0
Eremocarpus setigerus	1.8	0.4	T	0.7
1962–1963				
Acorn fragments	31.2	45.6	0.5	33.2
Lotus strigosus	1.9	6.8	T	3.8
Lotus americanus	18.9	12.2	46.1	19.8
Lupinus bicolor	6.0	6.8	T	5.5
Erodium spp.	3.2	T	0.9	1.4
Trifolium spp.	0.8	6.5	T	3.2
Eremocarpus setigerus	15.3	1.4	T	6.9

* Data collected from November-January, 1960-63. Information for 1937 based on Glading et al. (1940), November and December only.
† Trace.

MISCELLANEOUS PLANT SPECIES

Table 6 lists almost 40 species which contributed less than 1% by volume of quail diet during 1960–1963. With the exception of ripgut and soft chess, they compose a very small percentage of the total vegetation of the area. Some shrubs and mosses are listed but have not been included in the plant composition inventory.

Most of these less important species were found in less than 5% of the quail crops analyzed. Six species occurred in over 15% of the crops examined. Of these, red-stem filaree, soft chess, and popcorn flower were most important. They were taken in small quantities by many quail during the three study years. Windmill pink was eaten by many birds during two of the years. Ripgut seed and sedge leaves were consumed by many during a single season.

For most species, only the seeds were eaten. Exceptions were manzanita and mistletoe, which provided berries. Eleven species, each making up less than 1% of the fall diet, were recorded in the current study but

not in Glading's 1937 study. These species were present on the Experimental Range during the 1930's. Their appearance during the current study is perhaps due to better identification techniques, larger samples, or a combination of these.

TABLE 6

Food Plants Making Up Less Than One Percent of Fall-Winter Quail Diet During 1960–63, San Joaquin Experimental Range

Amsinckia	Fiddleneck
**Arctostaphylos mariposa*	Mariposa manzanita
**Astragalus*	Locoweed
Bromus mollis	Soft chess
Bromus rigidus	Ripgut brome
Bryophyta	Moss
Calandrinia caulescens	Redmaids
**Carex*	Sedge
Ceanothus cuneatus	Buck brush
**Ceanothus leucodermis*	Chaparral whitethorn
Centaurea melitensis	Napa thistle
**Centaurea solstitialis*	Yellow star thistle
Cuscuta	Dodder
Daucus pusillus	Wild carrot
Eleocharis palustris	Spike rush
Eriogonum	Buckwheat
Erodium cicutarium	Red-stem filaree
Erodium moschatum	White-stem filaree
**Euphorbia ocellata*	Valley spurge
Festuca	Fescue
Galium	Bedstraw
Hemizonia	Tarweed
**Hordeum vulgare*	Barley
Hypochoeris glabra	Smooth cat's ear
Lotus subpinnatus	Hairy lotus
Lotus	Trefoil
Lupinus	Lupine
**Medicago hispida*	Bur clover
**Melilotus indicus*	Sweet clover
Phacelia	Phacelia
Phalaris	Canary grass
**Phoradendron villosum*	Common mistletoe
Plagiobothrys nothofulvus	Popcorn flower
Plantago	Plantain
Rumex	Dock
**Sida hederacea*	Alkali mallow
Silene gallica	Windmill pink
Triticum aestivum	Wheat

* Not recorded by Glading et al. (1940) in 1937.

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GONAD STRUCTURE AND THE REPRODUCTIVE CYCLE OF THE KELP BASS, *PARALABRAX CLATHRATUS* (GIRARD), WITH COMMENTS ON THE RELATIONSHIPS OF THE SERRANID GENUS *PARALABRAX*[1]

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Histologic studies of the gonad of the kelp bass, collected at monthly intervals, showed that spermatogenic activity begins in April and continues through September. Late stage oocytes were present in May through September. Ripe follicular eggs indicated that spawning commenced in June and continued into September. The presence of a testicular lumen indicates that *Paralabrax* is a secondary gonochorist derived from a protogynous ancestor, and hypothetical steps leading to secondary gonochorism are postulated. In addition to the reproductive system, certain skeletal characters suggest that *Paralabrax* is allied to *Centropristes*.

INTRODUCTION

The kelp bass is one of the five most important game fishes in California. Young (1963) has presented a comprehensive review of this species and has evaluated the steps taken by the State of California to insure a continued yield. Although a considerable body of data on age and growth of the kelp bass is now available, our knowledge of its life history is far from complete. This paper is concerned with the fish's reproductive mechanism, which represents another in the series of specializations that have developed within the family Serranidae.

METHODS

Gonad specimens were removed and fixed in the field in Bouin's fluid. In the laboratory at The American Museum of Natural History they were transferred to Technicon S dehydrant, and a piece from the center of the organ was embedded in paraffin and sectioned at 7 microns. Duplicate slides were prepared; some were stained with hematoxylin and eosin, the rest with Masson's trichrome. Some of the material from frozen specimens gave poor results, probably because of poor fixation, but even these were adequate for the routine parts of the study. Serial sections through the genitalia were used for tracing the course of the sperm duct.

GONAD STRUCTURE

The ovary of *Paralabrax* resembles that of other marine serranids (Smith, 1965). In the female, right and left gonads are hollow sacs that join posteriorly to form a Y-shaped structure. The internal walls

[1] Submitted for publication February 1966.

of each ovary are lined with germinal epithelium folded into unequal but roughly parallel longitudinal lamellae, each of which is well supplied with central blood vessels. Germinal lamellae are absent from the common oviduct and from the ventral lateral part of each ovary. The muscle fibers of the outer walls are not organized into circular and longitudinal layers but run at varying angles to one another.

Development of the oocytes is generally like that of other serranids except that the eggs are held in the follicles longer. The senior author has examined sections of more than 300 ovaries from several species of *Epinephelus* and other genera of groupers and has yet to find a mature egg in its follicle. In *Paralabrax*, however, ripe ovaries contained advanced oocytes with eccentric nuclei (stage 5 of Kraft and Peters, 1963) and fully mature follicular eggs with thin membranes (Figure 1). In these mature eggs, the yolk platelets are no longer present and the ooplasm has a uniform, finely granular appearance. Such stages have been recovered from the lumen of the ovary of *Cephalopholis fulva* but never from the follicles. In the groupers the final stages of egg development apparently take place immediately before ovulation, or perhaps even after ovulation, but in *Paralabrax* the eggs mature in the follicle and are held there after their development is complete.

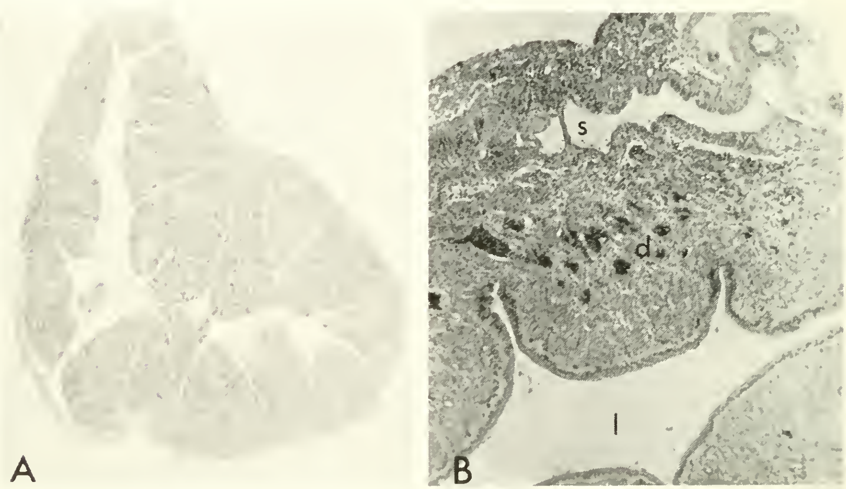

FIGURE 1. Cross sections of the ovary of *Paralabrax clathratus*. A—stage 5 oocytes. B—stage 6 (mature ovum) in the follicle.

The testes (Figure 2) are also hollow organs, similar in external appearance to the ovaries. This similarity makes it difficult to determine the sex of immature and sexually inactive individuals. The testicular tissue is also arranged in lamellae extending into the lumen, but the sperm do not enter the lumen as do the ovulated eggs. Instead they empty into lacunae in the wall of the testis by way of interconnected sinuses and finally pass into large spaces near the main blood vessels in the vicinity of the line of attachment of the mesorchium. Eventually the sperm enter a single duct in the posterior wall of the tube formed by the union of the right and left testes. The sperm duct

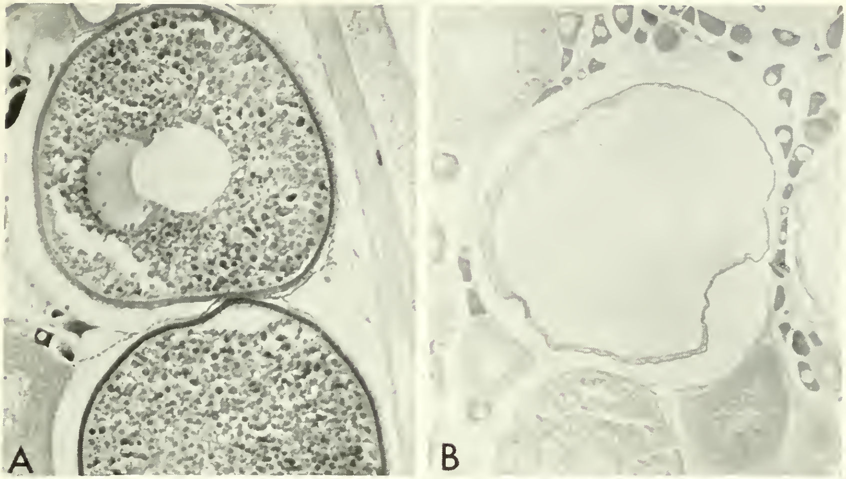

FIGURE 2. The testis of *Paralabrax clathratus*. A—complete cross section showing the germinal lamellae extending into the lumen. B—partial section through an inactive testis showing columnar epithelium lining the lumen. d—masses of cellular debris which may be the remains of unshed sperm. s—sperm sinuses. l—lumen.

joins the urethra near the tip of a short urogenital papilla. As in the female, there are no germinal lamellae in the common tube nor along the ventrolateral sector of the testis.

The lining of the testicular lumen is a columnar epithelium with basal nuclei (Figure 2B). The function of this epithelium, whose columnar nature is most apparent in inactive glands, has not been determined. It does not occur in the testes of *Epinephelus*.

Sperm are produced in crypts throughout the testicular lamellae. Toward the wall of the testis, these crypts are arranged in a linear fashion so that the organization of the testis approaches the tubular condition seen in many other teleosts. It should be noted, however, that the distinction between acinate and tubular testes is not clearcut (Smith, 1965, p. 17).

Sexually active male kelp bass have numerous crypts in which the sperm are arranged around the periphery with their tails extending into the lumen of the crypt (Figure 3). We have not observed this alignment in other serranids. Perhaps this indicates that the sperm are retained in the crypts just as the eggs are retained in the follicles but the significance of this retention, if indeed it does occur, is not apparent. Some gonads of both sexes contained masses of cellular debris consisting of phagocytes and amorphous brownish granules. In the ovary such material can be determined to be the last vestiges of unshed oocytes (Smith, 1965, pp. 6-7) but in the testes it probably represents the remains of sperm that were not released during the breeding season.

REPRODUCTIVE CYCLE

Although our sample is small, it seems to reveal the main features of the annual reproductive cycle. All months except October are represented by five or more females and all except October and December by three or more males. Since these specimens were all sexually mature,

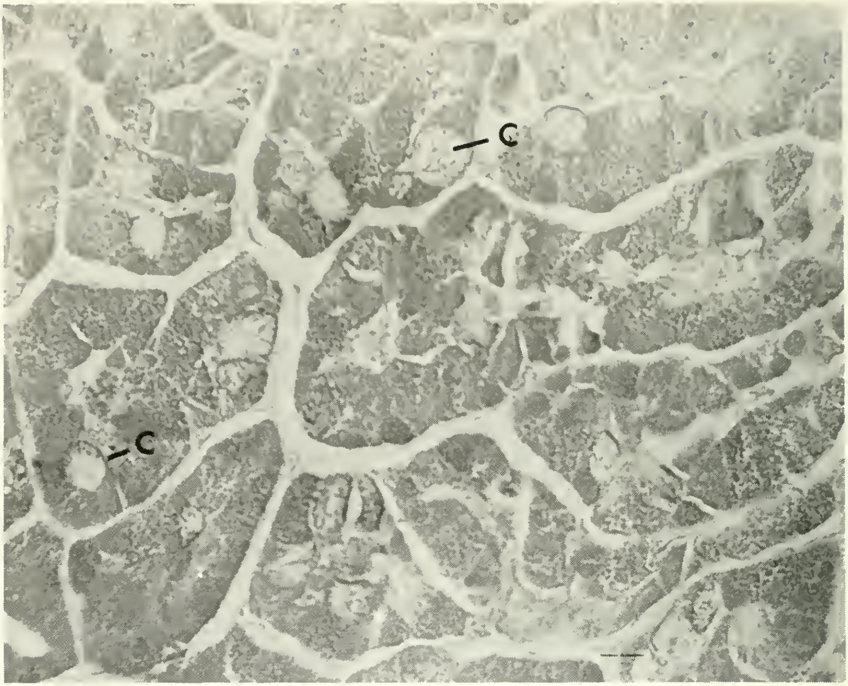

FIGURE 3. Section of a stage two testis showing some crypts with the sperm at the crypt walls.

although not necessarily sexually active, we are unable to establish criteria of maturity or to trace the ontogenetic development of the gonad.

For convenience in describing the cycle, ovarian classes are designated according to the most advanced oocyte stages present:

Class 1. This stage was not seen in our material, but stage 1 oocytes are very small, with a narrow ring of cytoplasm surrounding the nucleus. This is the earliest stage than can be definitely recognized as an oocyte.

Class 2. Stage 2 oocytes are the most numerous in all ovaries. They have very dark, nearly uniform cytoplasm.

Class 3. Stage 3 oocytes have less intensely staining cytoplasm. Vacuoles, zonae radiatae, and yolk platelets begin to appear at the end of stage 3.

Class 4. Stage 4 oocytes are characterized by the presence of yolk platelets and a thick zona radiata in addition to yolk vacuoles. The nucleus is located at the center of the cell.

Class 5. The nucleus has begun to move out of the center of the cell and a large vacuole is forming. The zona radiata is somewhat thinner than in stage 4. Yolk platelets still dominate the cytoplasm.

Class 6. Stage 6 ova are mature. The egg membranes are thin and the yolk platelets have disappeared, leaving a uniform, finely granular matrix.

Testicular classes are designated as follows:

Class 1. No sperm and no developing spermatocytes.
Class 2. No sperm but many developing spermatocytes.
Class 3. Abundant sperm and abundant developing spermatocytes.
Class 4. Abundant sperm, but no developing spermatocytes.

Our data (Figure 4) substantiate earlier observations (Young, 1963, p. 46) that spawning occurs during June, July, August, and September. Throughout these months some females were in class 6. Classes 4 and 5 were collected as early as May and as late as September, and this indicates that ova were still developing in September. Two class 3 individuals were taken in September. These had recently spawned, as evidenced by the remains of post-ovulatory follicles. From Novem-

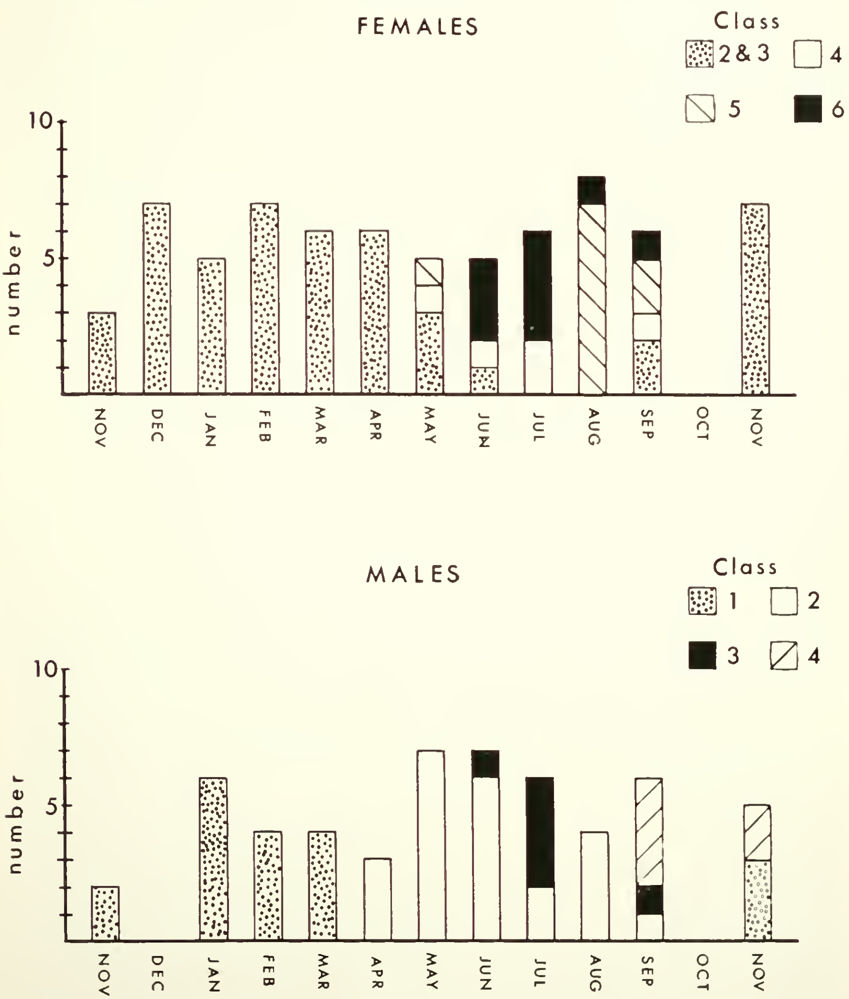

FIGURE 4. Annual reproductive cycle of the kelp bass. See text for explanation of classes.

ber through April only classes 2 and 3 were found. Thus, it appears that the ova begin to develop in late April or early May and reach maturity in June. Development continues until the following September, and by November all individuals are sexually inactive.

The male cycle is comparable. In April and May all males showed active spermatogenesis (stage 2) and by June some individuals had abundant sperm. By September four of the six males examined had ceased spermatogenesis, although many sperm still remained in the testes. A few of the November males also had abundant sperm but no developing spermatocytes. Most of the inactive males caught during the winter had abundant cellular debris that was probably the remains of sperm left in the testis at the end of the spawning season.

HERMAPHRODITISM

Most of the marine serranid fishes that have been studied carefully have been found to be hermaphroditic (Lavenda, 1949; Smith, 1959, 1965; Rheinboth, 1962). Several types of hermaphroditism, ranging from synchronous hermaphroditism to protogyny, have been recognized in the family. In some there are distinct male and female regions of the gonad; in others there is complete intermingling of the male and female elements. Because of the uncertain taxonomic relationships of the genus *Paralabrax*, it is of more than passing interest to determine what type of sexuality obtains in this genus.

Synchronous hermaphroditism, in which the male and female elements are present in the same individual and functional at the same time, is easily detected in serial sections and can usually be established merely by gross examination of the gonads. *Paralabrax* definitely does not have this type of hermaphroditism.

Protogyny, on the other hand, is difficult to demonstrate because the transition from female to male is complete and the sexes are separated in time, even though each individual functions first as female then as male. In order to establish the existence of protogynous hermaphroditism, it is usually necessary to examine a large series of histologic preparations, including some transforming individuals.

Males of protogynous species are larger than females, since the male phase follows the female phase while the fish continues to grow. Although there may be a wide range of overlap, because not all individuals transform at the same size, there is an increasing proportion of males with increasing size. No such pattern exists in *Paralabrax*. In our sample, females ranged from 224 to 485 mm TL (average of 71 specimens, 319.6 mm) and males ranged from 241 to 431 mm TL (average of 54 specimens, 311.1 mm). There was no increase in the proportion of males with increasing size and, in fact, the largest specimens were females.

Transformed males of protogynous species usually have some remnants of ova in their testes, but none has been found in the kelp bass. However, most of the inactive males in our sample had masses of amorphous cellular debris that appears to be similar to the final stages of oocyte degeneration (Smith, 1965, fig. 5B). Nevertheless, no other evidence of ova appear in the kelp bass testes and it appears that this material comes from the degeneration of sperm that remain in the

testes after the spawning season has ended. The presence of such cellular debris cannot be considered proof of the previous presence of oocytes.

In the gonad of the protogynous serranids, male elements are scattered throughout the germinal epithelium among the developing oocytes. Transformation takes place when the oocytes cease to develop and the spermatocytes begin to develop within proliferating seminiferous crypts. When this happens, the gross structure of the gonad remains unchanged and the lumen of the ovary is retained as a central cavity in the testis, even though it no longer functions to conduct germ cells. Primarily gonochoristic teleosts, on the other hand, have solid testes with seminiferous tubules leading into a central vas deferens. The presence of a testicular lumen indicates that the kelp bass is derived from a protogynously hermaphroditic ancestor and that functional change has preceded structural change. Such a change could easily have come about through the following series of steps:

1) In the protogynous ancestor, a few individuals transformed precociously, thus eliminating the functional female phase. This possibility is suggested in the data of Reinboth (1965), who found occasional small males in a population of the protogynous hermaphrodite *Centropristes striatus*.
2) Once the males that had not passed through a female phase became available in adequate numbers, there would be a selective advantage for females that did not transform, since such females would produce more eggs in succeeding years. In effect, transformation to the male sex is the equivalent of female mortality.

Selection for the development of secondary gonochorism would therefore exist.

SYSTEMATIC RELATIONSHIPS OF THE GENUS *PARALABRAX*

The serranid fishes are generalized perciforms, and in many cases their taxonomic alignment is based on the lack of specializations rather than on any apparent phylogenetic affinity. Subfamily divisions are particularly unsatisfactory, largely because of the lack of differentiating characters at this level and, indeed, the limits of the family Serranidae itself are still in question. It now appears that the most significant specializations are those of the reproductive system and that studies of the reproductive biology of these fishes can provide important clues to phyletic lines within the family.

The Eastern Pacific species currently assigned to *Paralabrax*, namely, *clathratus* (Girard), *maculatofasciatus* (Steindachner), *nebulifer* (Girard), *humeralis* (Valenciennes), *callaensis* Starks, *loro* Walford, *auroguttatus* Walford, and *albomaculatus* (Jenyns), seem to be closely related. Their general appearance is similar and they differ in such minor characters as scale size, coloration, morphometry, and extent of scutelation of the interorbital region. By analogy with the genus *Epinephelus*, we assume that their reproductive systems are similar and that they all are secondary gonochorists.

Robins and Starck (1961) have recently redefined the genus *Serranus* to include those species previously placed in *Serranellus*, *Paracentropristes*, *Mentiperca*, and *Prionodes*. These authors list 17 characters

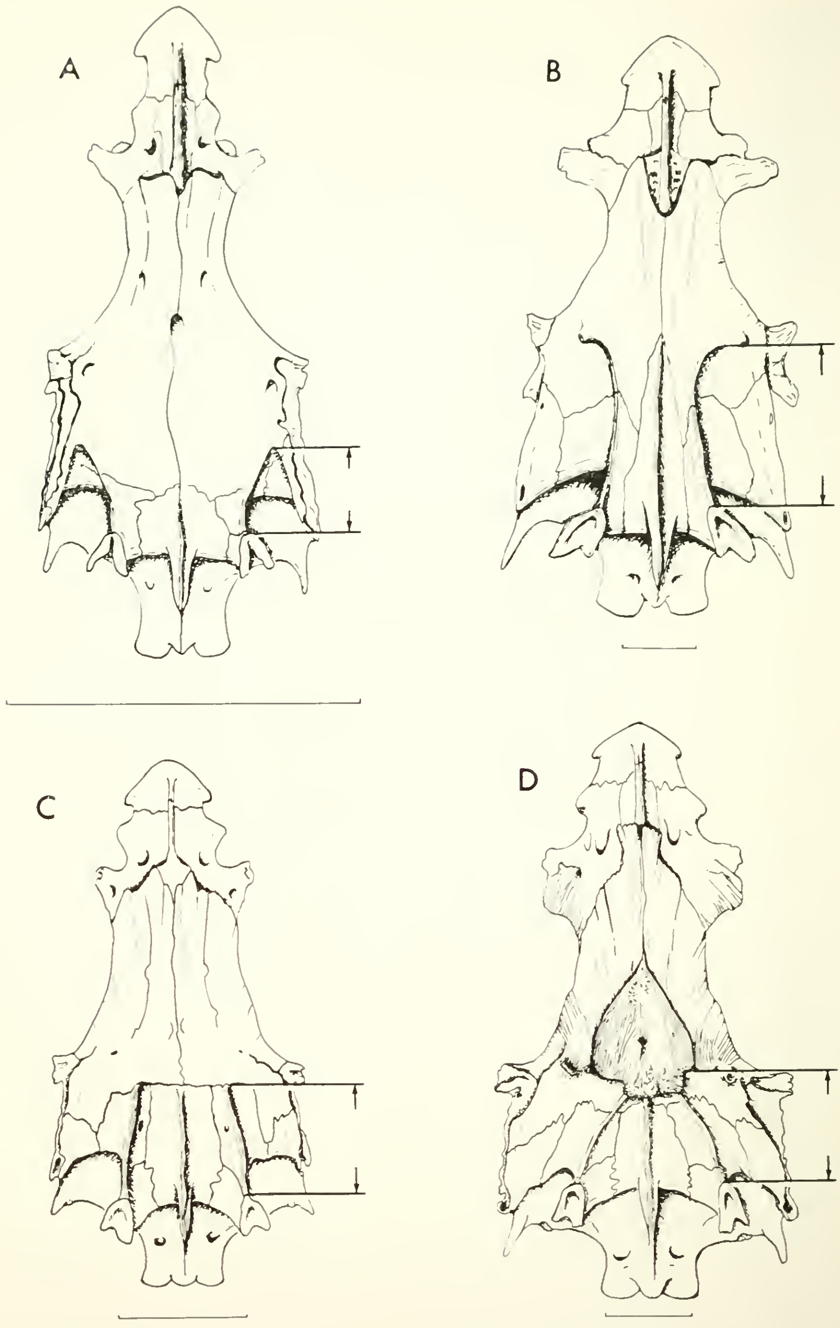

FIGURE 5. Dorsal views of the neurocrania of representative serranids.
A—*Serranus tigrinus.* B—*Epinephelus striatus.* C—*Paralabrax clathratus.* D—*Centropristes striatus.*
The base line equals one centimeter. Arrows show length of lateral skull crests.

that separate this complex of species from other perciforms, including synchronous hermaphroditism. Most of the 17 characters are also shared by *Paralabrax*, but *Paralabrax* differs in reaching a larger size and especially in not being a synchronous hermaphrodite.

In spite of the superficial resemblance to *Serranus*, we must look for the nearest relatives of *Paralabrax* among the protogynous hermaphrodites, since no other serranids are known to be secondary gonochorists. Those serranids known to be protogynous are the groupers (*Epinephelus* and its allies), *Rypticus*, and *Centropristes*. The groupers are so distinct that they are commonly placed in a separate subfamily (Jordan and Eigenmann, 1890) or family (Jordan, 1923, pp. 191–193). Their characters include the presence of a supramaxilla, 9 or 11 dorsal spines rather than 10, the tendency toward large size, and prominent lateral crests on the top of the neurocranium extending forward to the orbits.

Rypticus is a highly specialized form characterized by a drastic reduction in number of dorsal and anal fin spines, a thick muciferous skin, and a modified olfactory rosette. Gosline (1960) has placed *Rypticus* in the separate family Grammistidae.

Centropristes has a number of specializations, such as the shape of the caudal fin, enlarged pelvic fins, and considerable sexual dimorphism, even though it is a protogynous hermaphrodite. The male sexual characters that develop after transformation are prolongations of the dorsal, anal, and caudal fin rays and the formation of a *hyperostosis* of the frontal bones that is visible externally as a pronounced hump (Figure 5D). Such specializations appear to be of significance at the generic level rather than at the subfamily level. Baxter (1954, pp. 78–79) reported an abnormal kelp bass with elongate fin rays like those of *Centropristes* males.

The skulls of *Centropristes* and *Paralabrax* show certain similarities that indicate a close affinity (Figures 5C and D). In both there is a moderate development of the lateral crests which extend forward from the epiotics nearly, but not quite, to the postorbital processes of the sphenotics. The development of these dorsal skull crests is directly related to the degree to which the trunk muscles encroach upon the dorsal surface of the skull. In groupers the muscles insert as far forward as the orbits—in some genera to the middle of the orbits. Groupers also have a much longer postorbital cranium, so that the crests are $\frac{1}{3}$ to $\frac{1}{2}$ the entire length of the neurocranium. In *Serranus* (Figure 5A) the main muscle insertion is confined to the posterior skull, and therefore the supraoccipital and lateral crests are short. In both *Centropristes* and *Paralabrax*, there is an intermediate development of the crests.

Centropristes and *Paralabrax* are both temperate, rather than tropical, genera. *Centropristes striatus* lives as far north as the coast of Maine and *Paralabrax clathratus* is predominately a southern Californian species ranging north to Monterey. *Paralabrax humeralis* has been found off Peru and Chile. Species of both of these genera are of moderate size; *P. clathratus* reaches a maximum total length of about 28 inches, and *Centropristes striatus* reaches "two feet or more" (Bigelow and Schroeder, 1953, p. 408). In view of the extreme size of some groupers and the fact that species of the genus *Serranus* seldom reach

200 mm, considerable taxonomic significance may be ascribed to absolute size in this family.

Although these features suggest that *Paralabrax* and *Centropristes* are descended from a common ancestor and are closer to each other than to other extant serranids, the difference in sexual mechanism is sufficiently great to warrant their status as separate genera.

ACKNOWLEDGMENTS

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CALIFORNIA INLAND ANGLING SURVEY FOR 1964[1]

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Postal card angling surveys conducted periodically by the California Department of Fish and Game are designed to show trends in angling pressure and catches. Postal card questionnaires were sent to 0.8% of Californians buying resident licenses in 1964. Thirty-seven % of the cards were returned, giving a 0.3% random sample. The anglers were asked to record their catch and effort for the year by species or groups of species, namely, trout, panfish, black bass, catfish, and striped bass. Trout were the most popular fish, followed by panfish, catfish, black bass, and striped bass. Trout and panfish showed gains in total catch, while the other groups showed 9 to 28% decreases from the 1960 survey.

INTRODUCTION

In order to help determine needs of the angling public, the California Department of Fish and Game has conducted periodic angling surveys, covering a span of over 20 years. This is the eighth report of the series, covering the year 1964. Prior surveys have been described by Curtis (1940), Calhoun (1950, 1951, 1953), Skinner (1955), Ryan (1959), and Seeley, Tharratt, and Johnson (1963).

These surveys are designed to show trends in angling pressure and catches. *They are not meant to be interpreted as an accurate account of total annual catch or number of days spent fishing.*

This report is based on information received from successful resident sport anglers replying to a postal card questionnaire. The questionnaire used is so designed that information from unsuccessful anglers cannot be evaluated accurately.

METHODS

Postal card questionnaires were mailed to 12,215 license buyers,[2] representing 0.8% of the total resident licensees. Approximately 37% of these cards were returned, giving a sample of about 0.3%, slightly greater than that of previous surveys.

TABLE 1

Characteristics of the 1964 Survey

	Number	*Percentage*
a. Resident sport licenses sold	1,585,615	--
b. Questionnaires mailed	12,215	0.8 (of a)
c. Questionnaires returned	4,479	37.0 (of b)
d. Usable returns (at least in part)	4,405	98.3 (of c)
e. Respondents who did not fish	169	3.8 (of d)
f. Successful respondents	3,593	81.6 (of d)
g. Unsuccessful respondents	538	12.0 (of d)
h. Projection factor	570	--
i. Usable returns for species table (Table 2) *	2,785	62.2 (of d)
j. Mean days fished	11	--

* Some cards were usable in part but not for the species table.

[1] Submitted for publication February 1966.
[2] The name and address of every 25th person purchasing a license was recorded. One of every five such names was drawn at random and the individual mailed a questionnaire.

Many of the responses were unacceptable because of the deletion of information or obvious confusion in filling out the questionnaire. After excluding these cards, the total sample, usable for the entire scope of the questionnaire, was nearly 0.2% (Table 1).

The sample thus obtained was converted into statewide estimates by means of a projection factor, the number of resident sport fishing licenses sold divided by usable returned questionnaires (Table 2).

TABLE 2

Summary of 1964 Statewide Angling Survey

	Trout	Striped bass	Black bass	Catfish	Panfish
Postal card reports	1,634	425	457	596	685
Successful anglers	931,000	242,000	260,000	340,000	390,000
Standard error	14,800	10,800	9,500	12,000	13,000
Percentage of all licensees	51.4	15.4	11.0	22.3	27.3
Mean annual catch	35.5	8.2	15.2	27.1	47.4
Standard error	1.1	0.4	0.7	1.5	2.6
Median annual catch	21.0	4.5	8.1	11.0	19.6
Total annual catch	33,050,000	1,986,000	3,959,000	9,206,000	18,507,000
Standard error	1,100,000	178,300	262,500	529,000	884,000
Mean annual days	10.1	12.4	8.7	8.6	8.6
Standard error	0.2	0.6	0.5	0.5	0.3
Median annual days	6.0	6.7	4.2	4.3	4.1
Total annual days	9,407,000	3,004,000	2,226,000	2,922,000	3,358,000
Standard error	442,000	231,000	202,000	262,000	242,000
Percentage of total days	44.9	14.4	10.7	14.0	16.0
Mean catch per angler day	4.0	0.7	1.7	3.2	5.5

Possible sources of error, such as exaggeration, nonresponse, failure of respondent's memory, inability to differentiate between species, and confusion in completing the questionnaire have been pointed out in previous surveys. However, it is believed that the omission of non-licensed anglers partially counteracts the exaggeration factor. The inability of anglers to distinguish different species of fishes is avoided to some extent by grouping various species into general categories. The extent to which the survey is influenced by these factors is not known; therefore, the reader is cautioned not to accept the figures as true estimates. However, the effect of these factors is probably comparable from survey to survey, making the data valuable for following trends.

All inferences contained in this report assume that the sample is representative of the total angling population.

RESULTS

The results of this survey are presented in form similar to that of previous surveys, to preserve the continuity of the series.

This year, steelhead and ocean fish are excluded from the report because more accurate methods are used to obtain their catch and effort parameters.

Since 1953, certain species have been grouped in the surveys. "Trout" includes kokanee salmon and all trout except steelhead 1 pound and over. "Panfish" includes sunfish, crappie, and other warmwater game fish, with the exception of black bass and catfish, which are listed separately.

Frequency curves plotted from the data are similar in shape to a "J" written backwards, with a heavy concentration near the ordinate. Because of this, the mean is distorted by extreme values and is a poor measure of central tendency. The median, being less affected by extremes, is a better measure of central tendency. However, the mean is valuable in establishing and considering trends.

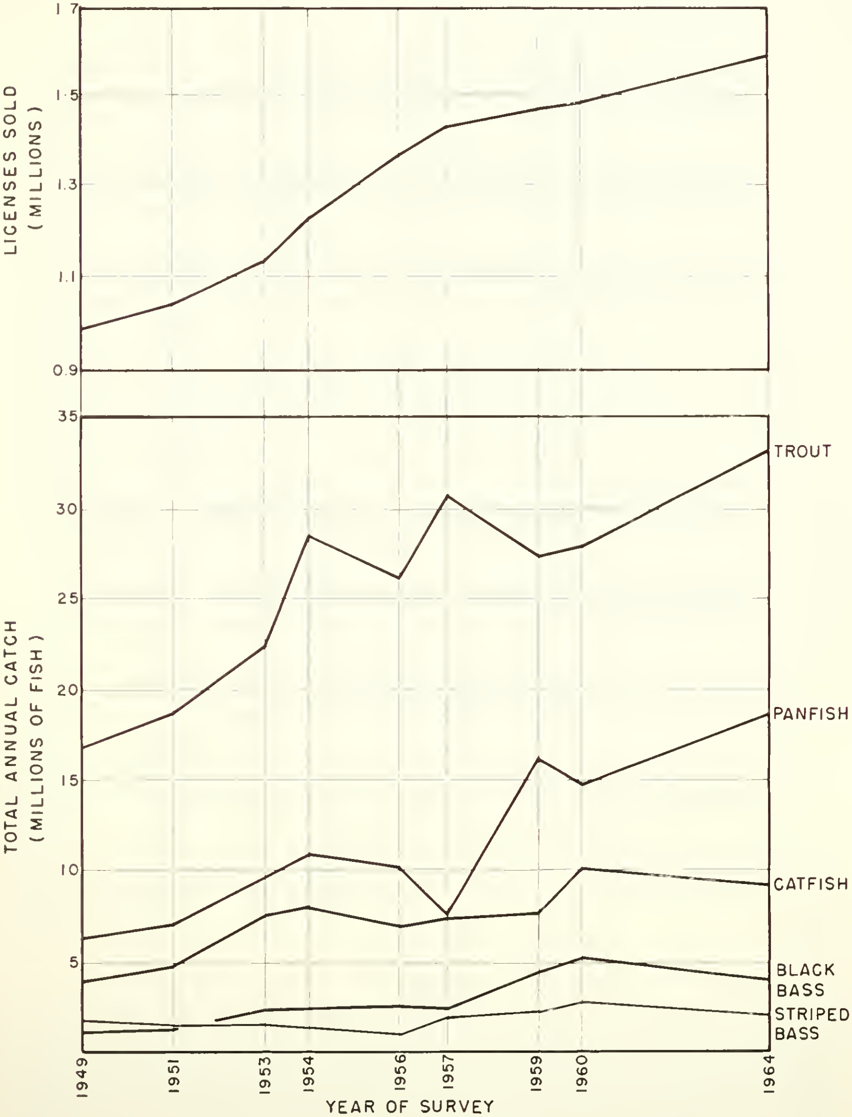

FIGURE 1. Trends in California sport fishing.

TROUT

Trout, long held in esteem by Californian anglers, have reached a new pinnacle in terms of total catch and angling pressure. Fifty-one % of the anglers caught trout in 1964 (Table 3, Figure 1). The resulting catch was 18% higher than in 1960. The mean and median annual catches have not changed significantly since 1956, probably reflecting the stabilizing effect of the Department's catchable trout planting program (Ryan, 1959).

TABLE 3

Trends in California Trout Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percentage of angling licensees	Mean	Median
1936	12,000,000	149,000	50	80	50
1937	11,900,000	151,000	48	78	50
1938	12,900,000	160,000	46	79	50
1939	12,800,000	179,000	49	71	37
1941	15,700,000	238,000	53	66	40
1942	16,400,000	234,000	54	70	42
1943	15,700,000	213,000	48	75	37
1946	17,660,000	357,000	47	49	25
1948	18,400,000	415,000	43	44	20
1949	16,700,000	431,000	13	39	--
1951	18,600,000	429,000	42	43	20
1953	22,300,000	530,000	44	42	22
1954	28,600,000	578,000	47	50	22
1956	26,200,000	640,000	46	41	21
1957	30,700,000	718,000	50	43	21
1959	27,480,000	660,000	45	41	21
1960	28,000,000	709,000	48	39	21
1964	33,000,000	931,000	51	36	21

STRIPED BASS

The striped bass, even with its limited distribution in California, has long provided anglers with thrilling sport. The 1964 survey showed a rather disappointing decrease of 28% in the total catch from the 1960 survey (Table 4, Figure 1). This is partially attributable to the late striped bass run and poor weather conditions, limiting the length of time fished daily and number of days spent fishing. To a limited extent, this is borne out by the slight decrease in the mean and median days fished; however, total annual days fished increased slightly (1.6%).

BLACK BASS

Black bass angling, long a favorite in the East and Midwest, is continuing to gain popularity with Californian anglers. The total catch was down 23% from the 1960 survey, but this should not cause concern, because the total catch trend is upward (Figure 1). The median annual catch was consistent with previous surveys (Table 5, Figure 1).

TABLE 4

Trends in California Striped Bass Angling

Year	Total catch	Successful anglers: Number	Successful anglers: Percentage of angling licensees	Annual catch per successful angler: Mean	Annual catch per successful angler: Median
1936	2,110,000	84,400	28	25	--
1937	2,040,000	81,900	26	25	--
1938	1,940,000	92,800	27	21	--
1939	1,880,000	89,300	24	21	12
1941	1,940,000	106,000	23	18	10
1942	1,680,000	88,200	20	19	--
1943	1,680,000	75,000	17	22	9
1946	1,380,000	113,000	15	12	6
1948	1,650,000	161,000	17	10	5
1949	1,750,000	165,000	17	11	5
1951	1,490,000	144,000	14	10	5
1953	1,590,000	166,000	14	10	6
1954	1,440,000	158,000	13	9	5
1956	1,000,000	127,000	9	8	5
1957	1,890,000	230,000	16	8	5
1959	2,260,000	224,000	15	10	5
1960	2,770,000	231,000	16	12	5
1964	1,986,000	242,000	15	8	5

TABLE 5

Trends in California Black Bass Angling

Year	Total catch	Successful anglers: Number	Successful anglers: Percentage of angling licensees	Annual catch per successful angler: Mean	Annual catch per successful angler: Median
1936	930,000	34,000	11	27	--
1937	849,000	33,000	11	26	--
1938	1,190,000	46,000	13	26	--
1939	1,340,000	67,000	18	20	--
1941	1,530,000	75,000	17	20	--
1942	1,340,000	66,000	15	20	--
1943	1,570,000	79,000	18	20	--
1946	1,700,000	104,000	14	16	--
1948	1,890,000	128,000	13	15	6
1949	1,160,000	116,000	12	10	5
1951	1,280,000	108,000	11	12	6
1953	2,300,000	161,000	14	14	9
1954	2,300,000	154,000	12	15	8
1956	2,550,000	164,000	12	16	9
1957	2,440,000	179,000	12	14	8
1959	4,493,000	218,000	15	20	9
1960	5,150,000	235,000	16	22	9
1964	3,959,000	260,000	11	15	8

CATFISH

Twenty-two % of the licensed anglers caught catfish in 1964. This is a new popularity record, and places catfish as third in importance, behind trout and panfish. Although the total catch was down 9% from 1960, there was a continuance of the upward trend (Figure 1). Both the mean and median annual catches have decreased from previous surveys (Table 6). Fishing pressure, indicated by the number of days fished, increased considerably over 1960.

TABLE 6

Trends in California Catfish Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percentage of angling licensees	Mean	Median
1936	2,940,000	38,000	13	78	--
1937	2,810,000	43,000	14	65	--
1938	3,480,000	48,000	14	72	--
1939	4,333,000	75,000	20	58	--
1941	6,100,000	97,000	21	63	--
1942	8,250,000	110,000	25	75	--
1943	7,060,000	101,000	23	70	--
1946	6,530,000	149,000	19	44	--
1948	5,560,000	182,000	19	31	15
1949	3,930,000	161,000	16	24	12
1951	4,710,000	171,000	17	29	12
1953	7,500,000	225,000	19	33	15
1954	7,990,000	220,000	18	37	13
1956	6,970,000	217,000	16	32	10
1957	7,370,000	259,000	18	28	13
1959	7,674,000	232,000	16	32	10
1960	10,100,000	275,000	19	37	15
1964	9,206,000	340,000	22	27	11

TABLE 7

Trends in California Panfish Angling

Year	Total catch	Successful anglers		Annual catch per successful angler	
		Number	Percentage of angling licensees	Mean	Median
1954	10,970,000	205,200	17	53	26
1956	10,020,000	225,000	16	44	18
1957	7,680,000	244,000	17	31	17
1959	16,114,000	281,000	19	56	22
1960	14,740,000	296,000	20	50	22
1964	18,507,000	390,000	27	47	20

PANFISH

Panfish, running second to trout in angling popularity, joined trout in showing an increase in total catch (Table 7, Figure 1) over 1960. Since 1954, the panfish catch in California has more than doubled.

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NOTES

AERIAL CENSUSES OF CALIFORNIA SEA OTTERS IN 1964 AND 1965

A remnant population of the once plentiful California sea otter, *Enhydra lutris nereis* (Merriam), occurs along the central California coast from at least Cayucos north to Año Nuevo Island. As recently as 1959 two otters were reported at Anacapa Island, but there have been no subsequent reports. After being reduced to virtual extinction through unrestrained exploitation by Russian and American fur hunters in the 1700's and 1800's, the sea otter has made a gradual comeback in the 1900's. By 1957, the population exceeded 600 animals (Boolootian, 1961).

Although it was generally believed the species was extinct in California by 1911, a few Department of Fish and Game wardens and other conservationists were aware that some otters had survived along the remote and inaccessible central California coast (Daugherty, 1965). Their presence became generally known in 1938, when about 50 animals were "discovered" off the mouth of Bixby Creek in Monterey County (Bolin, 1938).

In 1964, accurate up-to-date population counts were needed, so the Department undertook a series of aerial censuses. Three flights were made in 1964 and four in 1965 (Table 1). Present plans call for continuing the censuses on an annual basis.

TABLE 1
Aerial Counts of Sea Otters 1964 and 1965

Date	*Mean of observer counts*	*Observational conditions*
January 29, 1964	236	Good
February 13, 1964	345	Fair
May 15, 1964	387	Excellent
February 10, 1965	137	Fair
June 2, 1965	497	Excellent
September 15, 1965	330	Fair
December 2, 1965	296	Excellent

The Department's twin-engine Beechcraft was used for all census flights; these were conducted at altitudes between 50 and 250 feet. On all flights except that of September 15, 1965, the counts were made during the optimum hours between 10 a.m. and 2 p.m., when sea otters normally are relatively inactive on the surface in the kelp beds.

Richard A. Boolootian, University of California, Los Angeles, took part in the three census flights in 1964, and obtained good aerial photographs. Counts made from the photos were compared with visual counts to determine the accuracy of making visual counts of large herds of sea otters. Our individual counts proved to be conservative.

Dr. Boolootian's intimate knowledge of the sea otter's habits and previous experience in aerial censuses were of great value in our efforts to achieve proficiency in obtaining accurate counts of the shy otters. I took part in all of the flights except in February 1964, when Department biologist Malcolm S. Oliphant took my place. Captain Howard Shebley, Department of Fish and Game, Monterey, a careful observer of sea otters for many years, took part in all the censuses. Senior Warden-Pilot Al Reese, now retired, participated in all except the last (December 2, 1965). By using the same observers whenever possible, proficiency was acquired with experience, and we were more certain of maximum consistency.

Otters were observed along the mainland coast between Monterey Bay and a few miles north of Cayucos, lat. 35° 27′ N.; long. 120° W. All the Channel Islands were covered on the first flight on January 28, 1964, but no sea otters were found. Flights around the Islands were also made in June 1965, during a sea lion census (Carlisle and Aplin, 1966); again, no otters were observed.

DISCUSSION

Observers made independent counts on each flight, and these were then averaged. The counts varied considerably from flight to flight, ranging from 137 on February 10, 1965, to 497 on June 2, 1965 (Table 1). Weather and the distribution of the sea otters at the time of the flights are the factors which account for most of the variation. Many animals, probably including some that are diving as the plane passes over, undoubtedly are missed by the observers.

The sea otters were grouped in kelp beds when the highest counts were made, and widely scattered when low counts were made. Low counts usually prevailed during the winter censuses. When the counts made in January, February, and December are averaged, the mean number is 253; the mean of the counts made in May, June, and September is 404.

We do not know whether or not the otter population declined from the time of the 1957 count of 638 (Boolootian, 1961) to the time of our counts. Counting errors could account for some of the differences. Although the aerial census method is the best available, it does not provide a completely accurate count of the population. The differences between several of our counts were greater than the difference between our highest count and Boolootian's 1957 count.[1]

Some evidence indicates that sea otters are shot or speared each year despite stringent state and federal laws and every effort to enforce them. Also, there is evidence that sharks prey on sea otters at times, as teeth from the white shark, *Carcharodon carcharias*, have been found embedded in the abdomens of two dead sea otters (Orr, 1959). The killer whale, *Orcinus orca*, has also been indicted as an otter predator (Barabash-Nikiforov, Reshetkin, and Shidlovskaya, 1947).

As man encroaches more on the relatively remote remaining foothold of the sea otter in California, constant vigilance must be maintained

[1] The 1966 sea otter census flight was made on June 8, 1966. A slower flying Cessna 182, which provided better visibility for the observers than the Beechcraft, was used, and this may help explain the higher count of 591 otters between Cayucos and Monterey.

if this rare and beautiful mammal is to survive. Clean water is essential, as these animals cannot tolerate pollution of their environment. A small amount of oil on the sea otter's delicate coat will destroy its insulating properties and the animal will soon chill and die in the cold water (Kenyon, 1963). If pollution despoils their habitat, it may spell the doom of one of America's most prized animal species.

In the event pollution becomes a threat to the sea otter population along the mainland, serious consideration should be given to transplanting a number of otters to the remote outer Channel Islands, where they once occurred by the thousands. Such a transplanting program is showing encouraging results in Alaska (Karl W. Kenyon, pers. commun.). The population, instead of barely holding its own or gradually declining, might resurge through such a program.

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—*John G. Carlisle, Jr., Marine Resources Operations, California Department of Fish and Game, February 1966.*

THE INTRODUCTION OF WHITE BASS (*ROCCUS CHRYSOPS*) INTO CALIFORNIA

Chadwick and von Geldern (1964) concluded that the white bass should enhance angling in large warmwater reservoirs in California through increased utilization of open-water areas.

Following Fish and Game Commission approval, about 160 fingerlings (4 to 6 inches) were planted in Nacimiento Reservoir, San Luis Obispo County, on November 17, 1965. They had been seined from Lake McConaughy, a reservoir in Keith County, Nebraska under the supervision of Glen R. Foster, Nebraska Game, Forestation and Parks Commission and flown from Nebraska by commercial airline. They constitute the first plant of this species in California.

An additional 64 adults (23 males and 41 females) were released in Nacimiento Reservoir on February 17, 1966, near the inflowing Nacimiento River, where we expected them to spawn. They were obtained from Tenkiller Reservoir, Cherokee and Sequoyah counties, Oklahoma, through the cooperation of Leland E. Roberts, Oklahoma Department of Wildlife Conservation. They were flown to California by Carrol Faist and Leo Singer in the California Department of Fish and Game Beechcraft.

All fish planted appeared to be in excellent condition. Losses during transport were negligible and no post-planting mortality was observed.

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Chadwick, Harold K., and Charles E. von Geldern, Jr. 1964. The desirability of introducing white bass, *Roccus chrysops*, into California. Calif. Dept. Fish and Game, Inland Fisheries Admin. Rept. No. 64-11, 21 p. (Mimeo.)

—*Charles E. von Geldern, Jr., Inland Fisheries Branch, California Department of Fish and Game, March 1966.*

BOOK REVIEWS

Conservation of Natural Resources (Third Edition)

Edited by Guy-Harold Smith; John Wiley & Sons, Inc., New York, 1965; 533 p., illustrated; $9.95.

This book paints with a broad brush the overall conservation picture in the United States. It is both authoritative and concise, containing a good review of the history, development, and contemporary problems of natural resource use.

The various chapters are written by 19 different authors, each covering his particular field. It is well organized in textbook fashion, with numerous charts and photographs. This is the third edition. No comparison was made with the earlier ones.

Serious students of forestry, fish and wildlife, or recreation will find the brevity of coverage of these subjects dissatisfying. However, the subject matter is perhaps properly balanced, with major emphasis upon soils and waters and their commercial importance.

A noted shortcoming in the fisheries section is total emphasis upon commercial fisheries, with scarcely a mention of recreational aspects. All in all, though, this will still be classed as one of the better "facts and figures" type of texts covering the conservation field.—*Willis A. Evans.*

Practice of Wildlife Conservation (Science Edition Printing)

By Leonard W. Wing; John Wiley & Sons, Inc., New York, 1965; 412 p., illustrated; $2.65 (paper).

This publication is apparently the result of the author combining into book form his lecture notes from a typical beginning college course in wildlife management. It is both compact and concise, presenting a broad coverage of basic concepts and principles in few words. A good reading list of selected references is included after each chapter.

The book was originally published in 1951 and is currently being issued as a paperback under Science Editions. No attempt, however, has been made to update the contents. This is a serious drawback when specific subjects, such as status of waterfowl and other species, are discussed. Naturally, it does not reflect any techniques developed during the last 15 years.

The entire book, with the exception of two chapters, deals with game management. In these two chapters, an attempt is made to cover the field of freshwater fish management. Actually, in the reviewer's opinion, the book would have been better minus these chapters, since the coverage is fragmentary and quite dated. For example, the subject of artificial propagation is covered with these few sentences:

"The original emphasis on fry changed to emphasis on fingerlings and even larger fish. In some plans, the practice was established of releasing full grown fish but a few hours ahead of the hook. Although the past tense has been used here, these practices are still carried on to some degree in a few states."

Although the book is well written, both students and laymen will find any one of several recent books of more benefit to them.—*Willis A. Evans.*

Handbook of Applied Hydrology: A Compendium of Water-resources Technology

Edited by Ven Te Chow, McGraw-Hill Book Co., New York, 1964; 1418 p., plus index, 614 illustrations; $39.50.

Anyone who has the opportunity to use a book Dr. Ven Te Chow has edited or authored always finds that the information he is seeking can be readily understood and has been thoroughly researched. In fact, if we compare this book with similar books in the biological field, we might mention "Between Pacific Tides" by Ricketts and Calvin and "Game Management" by Leopold. Because these books are of such a specialized nature, it is sometimes difficult for them to be used readily by someone outside the field. Dr. Ven Te Chow and the 45 specialty contributors have used a number of devices to allow the lay person to use the book; e.g., brief, comprehensive introductions, outlines, and extensive bibliographies for each of the 29 chapters

covering the field of hydrology. Another device is the use of complete mathematical examples for the more intricate and difficult computations common to complex water problems.

To the fishery biologist the chapters of most use and interest would be those on Oceanography, Statistical and Probability Analysis of Hydrologic Data, Runoff, Sedimentation, Droughts and Low Streamflow, Quality of Water, and Water-resources Planning and Development. In like fashion the game biologist would find interest and use in the chapters dealing with Ecological and Silvicultural Aspects, Rainfall, Evapotranspiration, Infiltration, Hydrology of Urban Areas, Hydrology of Forest Lands and Rangelands, and Hydrology of Arid and Semiarid Regions.

As a reference work in another field, I believe that this book should be in libraries readily available to all biologists.—*T. P. Vande Sande.*

Fishes of the Western North Atlantic—Part 5, Orders Iniomi and Lyomeri

Giles W. Mead, Editor-in-chief; Sears Foundation for Marine Research, Yale Univ., New Haven, Conn., 1966; xv + 647 p., illustrated; $27.50.

Although 11 authors contributed material for this volume, one author alone, R. R. Rofen, was responsible for 382 of the 629 pages of text (18-page index not included). Among the 17 families covered (15 Iniomi and 2 Lyomeri), only two (Myctophidae and Neoscopelidae) were intended as "incomplete" or "interim" reports. However, because of the almost unbelievable lapse of time between submission of some reports and publication (over 3 years according to a footnote on page 603), a major portion of some of the coverage might be termed "incomplete" or "out-dated". While this shortcoming does hamper the usefulness of the volume, I suspect that with the accelerated exploration that has taken place during the past five years in all world oceans at depths at which these fishes reside, information regarding any one family, genus, or species might be outdated within a month.

Keys are offered for identifying genera on a world basis in all family accounts except Synodontidae (and Myctophidae and Neoscopelidae, of course). At the species level, however, only the Atlantic forms have been keyed out, unless the species has a worldwide distribution. Generally, the keys are easy to use, and those I tested yielded the right answers, but the trichotomous portions of the generic key to the Paralepididae left me cold.

Nomenclature for at least two eastern Pacific species has been altered by publication of this volume: *Magnisudis barysoma* becomes *Paralepis atlantica*, and *Alepisaurus richardsoni* becomes *A. ferox*.

The authenticity of a few bits of information is questionable but not of earth-shaking importance. For instance, juvenile *Alepisaurus* have *longer* (not shorter) snouts and heads relative to body length than adults (p. 486), and *Anotopterus does* have scales on its body (p. 498), although individual scales may be 6 inches apart on a large fish.

Although my criticism of the contents of this volume may seem adverse, it is meant to be constructive. Actually, Part 5 of FWNA fills a void that has long needed filling, and no serious ichthyologist or fishery worker should try to get along without a copy. Unfortunately, and on this point I intend to be extremely critical, the asking price for the volume is unreasonable even in these days of seeming prosperity. In view of the prohibitive cost of purchasing the entire series, perhaps we are fortunate that it has taken nearly 20 years to publish the first five parts.—*John E. Fitch.*

A Survey and Illustrated Catalogue of the Teredinidae

By Ruth D. Turner; Museum of Comparative Zoology Publ., Harvard College, Cambridge, Mass., 1966; 265 p., illustrated; $8.

The four major objectives in undertaking this study: (i) to make available a catalogue of all the names used in the family Teredinidae; to illustrate as many of the type specimens as possible, giving descriptive notes concerning them; and to indicate synonyms whenever this could be done; (ii) to survey the work that has been done on the systematics, biology, and distribution; (iii) to study the anatomy of as many species as possible and to relate the findings to the classification, evolution, and physiology of the Teredinidae; and (iv) to redefine the genera and to make a key for use in the generic placement of species, have all been admirably accomplished.

The several chapters that make up the two sections of this volume on the shipworms include an introduction to the family; an historical review; discussion of the fossil record; a genus-by-genus evaluation of the anatomy of the soft parts;

information on life history, trends in evolution, and characters used in identification; a key to the 14 genera; a catalogue of fossil and living teredos; a geographic listing of names; illustrations of type species; and an excellent list of references.

The 64 plates alone must represent a short lifetime of effort, since each plate illustrates several described species of teredos from a half-dozen different aspects (inner and outer views of shells, and inner, outer, and side views of pallets). All of the original figures used in these plates were drawn by the author, but three professional artists assisted in inking in some of the illustrations.

Considering the tremendous economic importance of teredos to all involved in marine biology, and in harbor maintenance or shipping or both, a prominent place should be reserved on their bookshelves for a copy.—*John E. Fitch.*

Crustaceans

By Waldo L. Schmitt; The University of Michigan Press, Ann Arbor, 1965; 204 p., illustrated; $1.95 (paper), $5 (cloth).

In this revision of the popular classic originally published in 1910, Waldo Schmitt has done a remarkable job of condensing a voluminous amount of knowledge into 204 pages of extremely interesting reading. I found the book informative, as well as entertaining. Although at times the author tends to leave the reader "up in the air", and craving more information. For instance, on page 131 he talks about the commensal relationship of the sipunculid, *Urechis*, and certain species of crabs that live in its burrows: "As in so many partnerships of this kind direct benefit to the host still remains to be demonstrated; but for the commensals the advantages of the association are many and obvious, and not the least of them is the prolonging of the breeding season in these species of crabs." This left me with the unanswered questions: what species of crabs, and how is the breeding season prolonged?

The author also tends to be anthropomorphic when discussing behavior, but not to the point of being distracting.

The book includes chapters on crustacean anatomy, physiology, taxonomy, ecology, and communication, with particular emphasis placed on malacostracans. The last two chapters are devoted to the importance of crustaceans to man.

The chapter on "crustacean conversation" was particularly thought provoking and should provide many hours of debate among scientists and laymen.

I strongly recommend this book to anyone interested in crustaceans, whether those interests be in their ecology, behavior, or simply in crustaceans as food.—*Daniel W. Gotshall.*

The Life of Fishes

By N. B. Marshall; The World Publishing Co., Cleveland, Ohio, 1966; 402 p., illustrated; $12.50.

"Fish . . . are masters of their medium." It would be difficult to disagree with Marshall's concluding words after reading *The Life of Fishes*.

Four broad fields are presented: day-to-day life, life histories, living spaces, and the diversity of fishes. Under these headings are included subjects such as form and motion, oxygen, association, behavior, reproduction, the deep ocean, shallow sea fishes, and freshwater habitats. Even though the author has attempted to cover a wide field he has been thorough in his endeavor; e.g., regarding the section on "The Capture of Oxygen", he describes the intestinal lung of such varied groups as the Cobitidae, *Callichthys*, and *Monopterus*.

Some attention is given to freshwater fishes; however, the author's interest lies mainly with marine forms. Since he does deal with the fish itself, regardless of habitat, both marine and freshwater biologists should be interested in this book. Marshall has joined academic observations and studies (214 references), including his own, into applied answers. For example, in dealing with form and motion the importance and use of each fin is demonstrated, thus assisting the fishery worker in fin selections for marking purposes. He may even be influenced into using another marking method after reading this chapter. Marshall has not supplied all of the answers, but rather has frequently posed questions for those who are searching for problems to solve. The selection of photographs, figures, and plates is excellent.

Fishery biologists will benefit the most from reading and rereading this book.—*James A. St. Amant.*

Pathway in the Sky: The Story of the John Muir Trail

By Hal Roth; Howell-North Books, Berkeley, 1965; 231 p., illustrated; $8.50.

Those who have not experienced the wonders of the John Muir Trail will find in Mr. Roth's book an interesting introduction to this section of the High Sierra. However, anyone who is looking for a detailed guide or description of the John Muir Trail country will be disappointed.

By means of excellent photographs and a casual though interesting writing style, the author does pass on to the reader some of the fascination and enchantement of the high country.

The book opens with an excellent account of the background history of the trail's conception. Succeeding chapters are headed "Yosemite Valley to Donohue Pass", "Silver Pass to Muir Pass", etc. This is somewhat misleading, since much of the material consists of colorful anecdotes or discussions of general topics not limited to any particular trail section. For example, he describes a typical commercial packer, a park ranger, bighorn sheep, deer management problems, golden trout, etc.

Although this book is not a technical report, the data presented are accurate and well documented. All in all, it is a most worthwhile addition to High Sierra book lore, which will allow the armchair traveler to gain an insight into the exhilarating features of the world famous John Muir Trail.—*Willis A. Evans.*

The Principal Diseases of Lower Vertebrates

By H. Reichenbach-Klinke and E. Elkan; Academic Press, Inc., New York, 1965; xii + 600 p., illustrated; $20.

Three previous separate books on diseases of fishes, amphibians, and reptiles by H. Reichenbach-Klinke are combined to form this volume, with additional material contributed by E. Elkan. The material has been translated from the German.

The three classes are covered in approximately equal separate parts. In each part the topics discussed are infectious diseases, which include bacterial, parasitic, fungal, and viral diseases; environmental and nutritional factors; tumors; and developmental abnormalities.

In each part, the authors also present sections on symptoms of diseases, killing and detailed examination of specimens, and rules on sending animals for investigation. There are also tables on treatment and tables of average life expectancy for many species. The authors have included sketches of relative sizes of red blood corpuscles to man's, as well as sketches of white blood corpuscles.

In each part, the authors refer to interrelationships between the three classes pertaining to service as common primary or secondary hosts. This is particularly of value to the fisheries student and professional, since members of the three classes are commonly found in close proximity within the same ecosystem.

Many examples are given of infectious diseases of the lower vertebrates that are transmissible to man.

The scope of the subject material is worldwide, which makes this volume especially valuable in view of the tremendous number of lower vertebrates being imported into the United States. Many of these are destined for private individuals who may intentionally or unintentionally liberate them into our native habitat, with possible dire results.

The authors have extended the pathology of fishes beyond that of aquarium species. Much space is devoted to the pathology of trout, salmon, and other game and nongame fishes.

The entire volume is profusely illustrated with excellent drawings and many photographs, and features a frontispiece in color. It also contains comprehensive glossaries, indexes, and tables. Because of the lack of published material available to the general public, particularly on the pathology of amphibians and reptiles, the numerous references to scientific journals should prove invaluable.

This book should serve as an excellent introductory parasitology reference text at the college level. It should prove to be very beneficial to professionals and nonprofessionals who maintain lower vertebrates in research laboratories and zoological collections.

I found the part on fishes to be particularly excellent and informative and a valuable addition to the few texts on this subject available to workers in the field of fisheries biology and management.—*R. G. Hulquist.*

Matrix Algebra for the Biological Sciences

By S. R. Searle; John Wiley and Sons, Inc., New York, 1966; xii + 295 p.; $9.95.

This timely book on matrix algebra, a shorthand algebra for handling many numbers simultaneously, was written for biologists and medical scientists. The discussions and concepts are presented at the secondary school level so that non-mathematicians in the biological sciences may utilize matrices for solving problems in biology and statistics.

As a non-mathematician, I found the material within the 10 chapters stimulating and comprehendible. The first 7 chapters develop the matrix concept through elementary operations, determinants, inverse matrices, rank and linear independence, linear equations and generalized inverses, and latent roots and vectors. Following a miscellanea Chapter 8, the last two chapters, dealing with linear models and regressions, were of particular interest for statistical use in computer analysis.

Extended use of biological and statistical illustrations and simple numerical examples is made throughout the book. Exercises for practical working experience of the concepts expressed are included at the end of the first eight chapters.

Matrix Algebra for the Biological Sciences is not a cookbook approach to understanding matrices. The book required concentration and considerable rereading to gain its fullest value. The exercises were challenging and thought provoking. For non-mathematicians like myself who have not used algebra for some time, an algebra refresher course would have facilitated a quicker understanding of some portions of the book. This should not detract, however, from the value of the stimulating concepts presented, particularly the application of the linear statistical models and regression analyses to computer techniques, contained in the last two chapters. —*J. Gary Smith*

Advances in Marine Biology, Volume 3

Edited by Sir Frederick S. Russell; Academic Press Inc., London, 1965; x + 402 p., illustrated; $13.50.

There has been an ever-increasing need for summaries of our knowledge in all phases of biology. With the present 'paper explosion' it is almost impossible for the biologist to keep abreast of all new findings in his field. This series, Advances in Marine Biology, helps to solve this problem.

The third volume contains four papers covering such diverse subjects as: Learning by Marine Invertebrates, Effects of Heated Effluents upon Marine and Estuarine Organisms, Aspects of Biology of the Seaweeds of Economic Importance, and Marine Toxins and Venoms and Poisonous Marine Animals. The four papers include over 1,300 references.

The paper on invertebrate learning includes studies on cephalopods, annelids, crustaceans, gastropods, lamellibranchs, platyhelminthes, echinoderms, and coelenterates. Studies of limpet homing behavior were particularly interesting, since the techniques might be applicable to movement and homing studies of other gastropods, such as abalone. One of the author's general conclusions was that if invertebrates are tested under appropriate conditions, "most animals can be shown to learn something, sometime".

Heated effluent pollution is the subject of the second paper. The author discusses the various possible effects of increased water temperature resulting from industrial use of water for cooling. The section on observed effects includes: elimination of native species, introduction of exotic species, and changes in breeding habits of endemic populations.

The paper on the biology of economically important seaweeds includes data from most of the countries that utilize marine algae for extractives, human food, animal food, or fertilizer. The author has included a list of all the major species used by man, and he discusses the life histories of the major genera. The methods used by various workers to measure standing crop should be of value in helping other countries assess and manage this valuable resource.

I found the last paper, which deals with venomous and poisonous marine animals, most interesting. There are few other areas of biology that contain so many "old wives' tales" and myths. The author, Findlay E. Russel, has done an excellent job of reviewing the historical and recent literature on the subject. He discusses the chemistry, toxicology, and clinical problems relating to the various poisons and venoms, as well as the distribution and biology of all known groups of poisonous and venomous marine animals. These groups include representatives of the phyla Protista, Porifera, Cnideria, Echinodermata, Mollusca, and several families of fishes. The

author's comments on methods of treatment for persons suffering from effects of fish venom were exceedingly enlightening, particularly his comparison of treatments advised in medical texts with those suggested by fishermen, lifeguards, and persons familiar with fish envenomations. He concludes, "that in most cases the non-professional advice has not only proved to be more effective, but often more rational". This section will be of great value to anyone working with fish or fisheries; e.g., Peace Corps workers will find this an invaluable aid in helping fishermen recognize and handle the various dangerous species of fishes and invertebrates.

I believe that this excellent volume will be of value and interest to biologists, phycologists, physicians, veterinarians, and fishermen.—*Daniel W. Gotshall*

The World of Coral

By Robert Silverberg; Duell, Sloan and Pearce, New York, 1965; 150 p., illustrated; $3.95.

This little volume is an excellent introduction to "The World of Coral" for the novice. The author begins by describing a coral reef as seen through the eyes of a skin diver swimming through an undersea garden. Mr. Silverberg then continues by discussing the builders and dwellers of a typical reef, followed by discussions of coral reef geography, scientific study of coral, the Great Barrier Reef, and coral islands and atolls.

The book is illustrated with black-and-white photos ranging in quality from good to poor. The book is well indexed, but the bibliography is inadequate. The text is well written and informative.

The interested amateur will gain much by reading *The World of Coral*. The low cost of this book is such as to make it a worthwhile reference volume for both amateurs and professionals.—*Michael L. Johnson*

Fishes of the World in Color

By Hans Hvass; E. P. Dutton & Co., Inc., New York, 1965; 156 p., illustrated; $4.95.

This concise book contains color drawings of over 1,000 species of fishes. Each drawing is accompanied by brief notes on biology and distribution. The drawings by Wilhelm Eigner represent the most valuable portion of the book, and these are only of fair quality. Most of the drawings are poor approximations of the subject, both in shape and in coloration. The text contains only fragmentary information on each species, and in most cases this is so general as to be almost worthless to the professional fishery biologist.

Commercial and sport fisheries are emphasized, with many examples of tropical and bizarre species included. Marine and freshwater species received about equal coverage. The species are arranged in reverse order to that normally used by taxonomists. An index is included, but only the popular names are listed.

All in all, this volume will be a disappointment to most fishery workers. It will be of limited benefit to interested amateurs.—*Michael L. Johnson*

Fish as Food, Vol. 4: Processing, Part 2

Edited by George Borgstrom; Academic Press, Inc., New York, 1965; xv + 518 p., illustrated; $18.50.

This, the final volume of a series, is a compilation of articles written by 16 authors, 11 of whom are from foreign countries. It includes discussions on freezing, canning, preservation, processing, freshness tests, and handling of fish. With authors from over the world, the book achieves broad coverage and gives an insight into practices in other countries, as well as in the United States.

The section on handling of fresh fish is well written and easy to read. The author has tied the references together neatly and presents practices that would improve handling. The section on freshness tests covers the field well, but the reader's trend of thought is often interrupted by lists of references in the text, although 27 pages of references are presented at the end of the chapter. It is of interest to note that despite all the possible tests, general opinion holds that sensory judgment is still the best means of evaluation. The chapter on fish canning is very well written, and presents many aspects of canning, as well as means of determining and preventing spoilage. However, retort time for processing is not given; the reader is referred to other publications.

Such a comprehensive publication should present some examples. The chapter on the tuna fishery is not up-to-date. The most recent reference listed is 1951. The California tuna fishery has undergone a complete revision to purse seining since

1958. This change is acknowledged by a single sentence, and no mention of it appears in the section on fishing methods. The three chapters on sardine canning contain mistakes in tables. The can size in inches in one table is listed as ranging from 315–802 in., which would mean cans from 26 to 67 feet in length. Even if we consider the lack of a decimal point, the conversions are still incorrect. In another table, the can height is given in milliliters.

In the section on heat processing of shellfish, the author states that the king crab fishery in the U. S. is minor. Since 1960 the value has ranged from 2.8 to over 7 million dollars, with landings up to 85 million pounds.

Scientific names are not used consistently. The albacore is listed as *Thunnus thynnus orientalis* in a table in the text and *Thunnus alalunga* in the species list in the back of the book. *Thunnus thynnus* is a synonymous name for the bluefin tuna. The blue rockfish, *Sebastodes mystinus*, is incorrectly listed as *Sebastosomus mystinus* in the table of common important species, but actually contributes little to the commercial rockfish catch. The author may be following the 1930 check list of Jordan, Evermann, and Clark, which is antiquated in this regard.

Despite the mistakes and lag in publication time, the book is a fine reference and presents guide lines in processing that would definitely improve the industry, especially the handling of fresh and frozen fish, which really determines the quality of the final product. It is a good addition to the fine work that preceded it.—*Richard L. Poole*

Developments in Handling and Processing Fish

By G. H. O. Burgess; Fishing News (Books) Ltd., London, 1965; 132 p., illustrated; $4.

In three interesting and informative chapters, the author has traced the historical development of handling and processing fish, related current technical problems, and presented future thoughts about the British fish industry. The chapters, on i) fresh fish, ii) the traditional methods (smoked and cured fish), and iii) freezing and the future, were originally presented as a series of lectures sponsored by the Buckland Foundation.

Two services are performed by this book. First, an historical record of the progress in handling and processing methods to satisfy the consumers' choice of fish products has been printed. Second, and more important, it portrays the need for better handling and processing methods to maintain consumer demand. On this point, Dr. Burgess points out the need for fishermen, industry, and science to work toward quality control. Better handling at sea, better processing methods ashore, and better preserving methods are discussed in relation to achieving practical quality control measures.

The last few pages are devoted to thoughts on the future of the fishing industry; this section in itself, I believe, makes the book worth reading. Much of the information in this book could apply equally well to the American fish industry, particularly the last section on the future of the industry. I believe that American fishermen, industrialists, food technologists, and fishery researchers will find *Developments in Handling and Processing Fish* in their reading interest.—*J. Gary Smith.*

Modern ABC's of Fresh Water Fishing

By John Crowe; Stackpole Books, Harrisburg, Pa., 1965; 192 p., illustrated; $4.95.

I read this book with great interest and found it to be so full of useful information that it was hard to put aside. It is written by an author who knows what he is writing about. His approach to angling for any kind of fish seems to be "use the bait or lure that is most effective"; what could be simpler or more logical? If one wants to catch fish he should be prepared to go about it in the best way. The author makes a number of points concerning tackle which are virtual truisms. Among them are: good quality costs money but is economical in the long run through satisfactory use and long, maintenance-free life; rod material is unimportant, either bamboo or glass is satisfactory; in casting rods the style of handle means very little, pick one you like and practice with it for expertness; if you can't have a variety of equipment pick general purpose items, but buy the best quality possible.

Individual chapters are devoted to methods and techniques of catching the most important kinds of game fishes, including trout, bass, pike, muskies, walleyes, pickerel, and panfish. The main emphasis in each chapter is on *basic* methods and techniques that have been devised to catch fish. Other chapters briefly cover life histories of certain highly prized fishes in more detail than the earlier chapters on groups of fishes. Examples are rainbow, brown, and eastern brook trout, and the

pikes. Fly tying, lure making, useful knots, and tips on tackle are illustrated in a series of sketches. There is even a chapter on general fish physiology, which briefly includes age and growth using scales, protective coloration, the lateral line functions, respiration, instinctive reactions, and hunger.

This is a good book, written by an expert to fill a basic need for information by beginners. The only fault I found with it concerns its brevity. Many sections were awfully short. But I realize that we can't expect everything in only 192 pages.—*J. H. Ryan.*

Tuktu: The Caribou of the Northern Mainland

By Fraser Symington; Canadian Wildlife Service, Ottawa, 1965; 92 p. + map, illustrated; $2.

This book is an effort to bring to the attention of the Canadian public the caribou problem. It poses the question ". . . whether to try to save the caribou or allow them to decline still further to the verge of extinction."

During the past 65 years, there has been a decline in the barren-ground caribou from 2–3 million to about 200,000. It is pointed out that there are probably many factors that have contributed to this decline, but studies have indicated that the main factors are probably excessive human kill and range depletion by fire as a result of increased human activity.

This work draws on the long-term studies that have been conducted on caribou by the Canadian Wildlife Service.

The author was trying to reach the Canadian people and has not included footnotes, literature citations, or a bibliography. Some scientists may feel this is a shortcoming, but citations and footnotes probably would have been a distraction to the average interested citizen, to whom this work is directed. In my opinion Symington has done an excellent job of presenting both the biological and sociological aspects of the caribou problem. It is to be hoped that this work is successful in awakening the people of Canada and others throughout the world to the need for decisions and coordinated action if caribou populations are going to be managed scientifically and remain an important part of arctic life. *Wallace G. Macgregor.*

Muskoxen in Canada

By J. S. Tener; Canadian Wildlife Service, Ottawa, 1965; 166 p. + map, illustrated; $3.25 (paper).

This monograph is based on studies conducted since 1951. The author spent eight years in the Canadian Arctic working on muskoxen.

The biological and life history information is remarkably complete and will no doubt be a surprise to many workers in the wildlife field in the United States. As well as general life history studies, excellent studies were conducted on the range, including chemical analyses of muskoxen food plants.

In a taxonomic review of the species the author concludes that all living muskoxen should be assigned to one species, *Ovibos moschatus*, with no subspecies.

It is encouraging that following the near extermination of muskoxen by overutilization and other factors their numbers have increased under protection, and it appears that this unique animal, which is so magnificently adapted to the arctic tundra, will not go the way of the great auk.

Also included with this publication is an excellent map of the Canadian Arctic that to persons interested in this area is well worth the price of the book.—*Wallace G. Macgregor.*

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AUTHOR

SCIENTIFIC NAMES

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Notice in hereby given, pursuant to Sections 206, 207, and 208 of the Fish and Game Code, that the Fish and Game Commission shall meet on October 7, 1966, at 10:00 AM, in the Auditorium, Resources Building, 1416 9th Street, Sacramento, California, to receive recommendations from its own officers and employees, from the Department of Fish and Game and other public agencies, from organizations of private citizens, and from any interested person as to what, if any, regulations should be made relating to fish, amphibia, and reptiles, or any species or subspecies thereof, for the 1967 sport fishing season.

Notice is hereby given, pursuant to Section 206 of the Fish and Game Code, that the Fish and Game Commission shall meet at 10:00 AM, on November 4, 1966, in the Supervisors' Chamber, Shasta County Courthouse, Redding, California, for open public discussion of, and presentation of objections to, the proposals presented to the Commission in October and to publicly announce the regulations it proposes to make relating to fish, amphibia, and reptiles for the 1967 sport fishing season.

Notice is hereby given, in accordance with Section 206 of the Fish and Game Code, that the Fish and Game Commission shall meet on December 9, 1966, at 10:00 AM in Room 1138, New State Building, 107 South Broadway, Los Angeles, California, to hear and consider any objections to its determinations and proposed regulations in relation to fish, amphibia, and reptiles for the 1967 sport fishing season, such determinations and orders resulting from the hearings held on October 7 and November 4, 1966.

Fish and Game Commission
Monica O'Brien
Secretary to the Commission

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